PHYTOPATHOLOGY

VOLUME V NUMBER 6

DECEMBER, 1915

THE GROUPING AND TERMINOLOGY OF PLANT DISEASES

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Considerable interest has recently been shown by plant pathologists concerning the classification of plant diseases, and the necessity and possibilities for further research in the so-called physiological plant disease group. Smith[1] has recently shown that our knowledge relative to physiological diseases in general is inadequate and that the necessity for more thorough research in this group of diseases is imperative. This has been further emphasized by Grossenbacher,[2] who clearly demonstrates the necessity of investigational work in certain neglected phases of phytopathology, namely, the development and maturation of abnormal plant tissues, particularly with reference to the effects of environment. The vagueness of the term physiological plant diseases, the indefinite knowledge regarding their causes, and the practical significance of the lack of the element nitrogen in plant nutrition, as the possible cause of some physiological diseases, is forcibly stated by Lipman.[3]

It appears to the writer that certain facts relative to the meaning of the term physiological plant diseases have been overlooked, and furthermore, the scope and number of plant diseases occurring in this group have become more complex as time has elasped, without proper readjustments. It is not with a didactic attitude, nor the thought of criticism, that the writer offers the following suggestions; he assumes the rôle of an interested student in phytopathology, dealing with facts as they appear, and not that of a connoisseur of the subject.

Since the writer became interested in plant disease investigations, his understanding and interpretation of the use and meaning of the expres-

[1] Smith, R. E. The investigation of physiological plant diseases. Phytopath. **5**: 83–93. 1915.

[2] Grossenbacher, J. G. Some neglected phases of phytopathology. Phytopath. **5**: 155–162. 1915.

[3] Lipman, Chas. B. A suggestion of a new phase of the problem of physiological diseases of plants. Phytopath. **5**: 111–116. 1915.

sion, "physiological disease," have been as vague and indefinite as the term has been loosely used. It has been easier for plant pathologists to place a plant malady in the physiological disease category, than to conclusively demonstrate by means of histology, parasitology, cytology or biochemical investigations that it belongs in a more definite group. Furthermore, it is unfortunate that plant pathologists have been employing the term, physiological disease, to include a group of non-parasitic diseases. In order to reach a better understanding, and with the idea in mind that some of the suggestions herein contained may be of help in arriving at some definite conclusions, the writer is attempting to present his views on the professional use of the term, physiological plant disease.

The following suggestions and statements are made with two fundamental ideas in mind. First, the term physiological plant disease, as employed by the plant pathologist, lacks scientific meaning. Within the profession its present use is possibly understood, and so far as this is concerned, its immediate requirements may be met. We are attempting, however, to assign to this term a meaning which, from a scientific viewpoint, is fundamentally misleading.

Second, we are not lucid or explicit in the separation of the various kinds or groups of diseases into (1) physiological diseases, (2) those of undetermined origin, and (3) fungous and bacterial diseases. It is the writer's purpose, in part, to show that what is regarded in some cases as a physiological disease should more properly be placed in the undertermined group, while others should be placed in a group which is etiologically unrelated to pathogenic organisms.

To go back to the first criticism, namely, of the use and meaning of the term physiological diseases; this expression is apparently a favorite among plant pathologists. Heretofore, when an investigator has been at a loss as to the etiology of a plant trouble, it has been branded a physiological disease. How many have actually analyzed the meaning of this expression? It is obvious that the term thus used indicates little correlation of scientific facts. Plant physiology deals with the functioning of a plant, regardless of whether that plant belongs to the phylum Schizophyta, Mycophyta, or Anthophyta. The very fact of a plant's developing and growing in intimate relationship with another plant, symbiotically, parasitically, or otherwise, involves the further fact that it carries on those vital, inherent, physiological processes peculiar to itself, independently of the associated plant. The two are separated individuals and their capacity to exist depends upon their independent, internal activities. The benefit or injury which one of these plants may derive from, or impose upon the other is entirely a different problem, involving, besides physiological phenomena, the most intimate and intricate relations between them. In

both, physiological phenomena play their independent, inevitable rôle, the importance of which can readily be understood.

This might be further exemplified by considering group 3, i.e., plant diseases of fungous or bacterial origin, as compared with other diseases. Plants affected by maladies belonging to this group likewise have their vital functions interfered with. It matters little, however, whether it is a direct case of malnutrition, or not; the host ceases to function normally, but in this instance the abnormal condition is known to be caused by the inroads and advances of one plant form over the other, producing unbalanced physiological phenomena in the host. It is obvious that all plant diseases belonging to this group involve physiological disturbances, and it must be just as evident that the various inherent, physiological phenomena produced by the host and by the pathogene are carried on independently of each other. Therefore, it appears that this group contains plant diseases which are just as definitely physiological in nature as are those of group 1.

The ultimate causes of many of the physiological diseases are unknown or undetermined, a fact which has already been brought out; but since there is a physiological disturbance, as in all plant abnormalities, regardless of their cause, the matter is dismissed for the time and the name "physiological disease" is given. What this conveys in pathological terms and what it actually expresses leads to some confusion, or at least shows it to be a misnomer—for in truth all plant diseases are physiological phenomena. According to the writer's conception, this expression conveys the idea of a disease having specific symptoms, not known to be produced by pathogenic organisms as far as investigations show; its cause may be known, or it may be undetermined, possibly inherent or self-induced, abnormal, and interfering with the normal functioning of the host. For example, the so-called enzymic disturbances, such as peach yellows, little peach and the mosaic disease of solanaceous plants; the straight head of rice and oat blast (thrips?); such maladies as exanthema, bitter pit of apples, lightning injury, leaf scorch, and sun scald; such troubles as leaf roll of potato, chlorosis, œdema, blossom-end-rot of tomato and brachysm in cotton—all these have been arbitrarily placed in this one group. The list could be greatly enlarged, but examples are so familiar to plant pathologists that it is unnecessary to further enumerate.

Since it has been the writer's intention, in part, to show that the term, physiological disease, is not a desirable name for this group of ailments, it might be advisable to offer a substitute. It would appear as though the term, non-parasitic diseases, would be more appropriate—a term which is employed by European investigators, but which seems to have been avoided or overlooked by plant pathologists in this country.

The second point which the writer desires to make is, that the types of disease generally included in the physiological group are too varied in nature to be classed all together. It would seem desirable that some of these should be placed among those plant maladies, the real cause of which is undetermined. These would include those types which can be produced at will by one of the methods of artificial inoculation or infection, in which tissues or juices of diseased plants are employed, such as the mosaic disease, peach yellows, curly-top of sugar beet, and so forth.

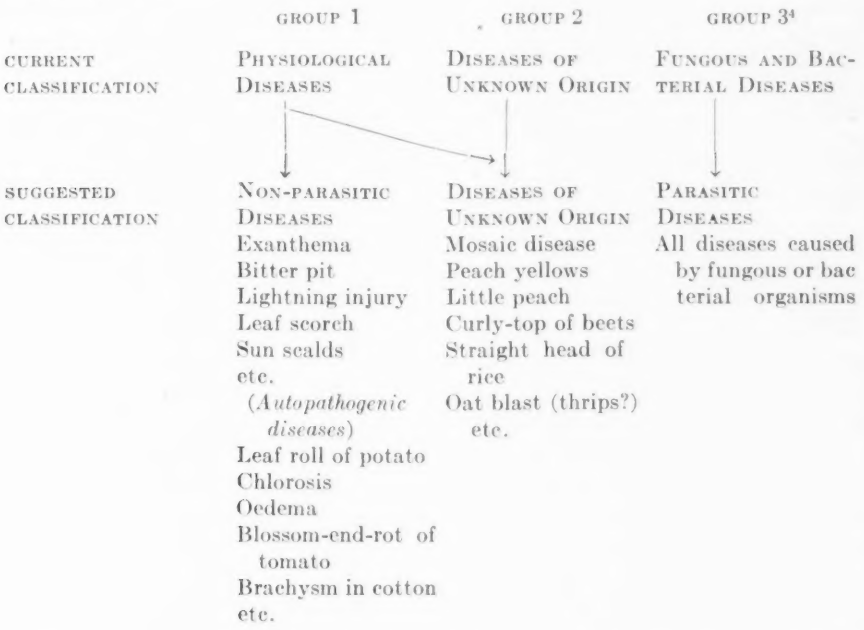
A certain analogy can be drawn between the undetermined group and the Deuteromycetae, or Fungi Imperfecti. The Deuteromycetae are placed in the scheme of classification under the Mycophyta, and between the Ascomycetae and Basidiomycetae, because of the possibility of revealing a phylogenetic relationship to a Basidiomycete instead of an Ascomycete. The undetermined group of diseases might be considered in a similar manner. Is it not possible that this group may disclose plant diseases of a mycological, bacteriological, or possibly some day, of an ultramicroscopic nature? This has been found to be the case with gummosis of cherry and lemon, and western tomato blight, at one time considered physiological diseases. If diseases of a doubtful nature are kept in the undetermined group until more thorough studies have been completed, and investigations conclusively confirmed, it would be possible properly to classify them. Until then it becomes necessary to have a tentative but at least not incorrect grouping.

The question arises whether there are not still others in the group of physiological diseases which are of undetermined origin. Certain maladies in this group, which are brought about by something possibly inherent, self-induced and pathogenic, cannot be produced at will as, for example, the hereditary trouble in cotton known as brachysm, chlorosis in plants, potato leaf roll, œdema in plants and perhaps the blossom-end-rot of tomato. Such diseases are to be considered non-parasitic, and are as it were, autogenous in nature. They should perhaps be separated from all others and given a sub-group name. That such a class of *autopathogenic* diseases—if we might coin the term—may be of greater importance than generally considered is to be interpreted from the recent article by Grossenbacher.

It appears to the writer that in this country plant disease investigations have been somewhat too narrowly limited to the mycological aspect of phytopathology. A study of the host is too frequently slighted if not neglected. Adequate emphasis has not been placed on the intricate problems involving non-parasitic diseases, and furthermore, it would seem that pathological conditions produced by animal parasites should not be omitted from the plant pathologists' field of research. Do not the sci-

ences of human and veterinary pathology include all pathological conditions of animals? Can an entomologist, zoologist or "plant pathologist" be a competent diagnostician with but a partial knowledge of the diseases of plants?

The accompanying diagram will aid in an understanding of the following recapitulation:



The groups as they now stand in their current classification, together with suggested changes, are:

Group 1 comprises in the current classification, all the diseasees listed under groups 1 and 2 of the suggested classification, i.e., such diseases as peach yellows, little peach, mosaic disease, curly-top of beets, maladies which are transmissible and may be due to some undiscovered ultramicrosopic organism; straight head of rice and oat blast; such non-parasitic diseases as exanthema, leaf scorch, lightning injury, sun scald and bitter pit of apples, which are anatomico-physiological derangements; and such ailments as, leaf roll of potato, chlorosis, œdema, blossom-end-rot of tomato and brachysm in cotton, which may be more or less self-induced, inheritable in some cases, and unquestionably pathological in nature.

[4] If maladies due to insect and other animal parasites are to be included, logically they would be placed in this group.

Group 2 contains plant diseases of undetermined origin.

Group 3 contains plant diseases of fungous or bacterial origin.

According to the writer's ideas the following arrangement may be offered as a suggestion.

Group 1 should be renamed non-parasitic diseases, with the possible sub-group as already suggested; namely *autopathogenic* diseases. This main group should contain only plant diseases which are definitely known to be of non-parasitic nature, and all others heretofore classified in the physiological group, should be placed at the discretion of the Society in group 2, or the undetermined group.

For the rest, group 2 and group 3 should remain as they now stand. The suggested change in the name of group 3 from fungous and bacterial diseases to parasitic diseases is thought advisable.

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AN ANTHRACNOSE-RESISTANT RED KIDNEY BEAN

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WITH FOUR FIGURES IN THE TEXT

Since 1910, the writer has been working on the resistance and susceptibility shown by varieties of the common bean (*Phaseolus vulgaris*) to anthracnose, caused by the fungus *Colletotrichum lindemuthianum*. Four years ago it was shown[1] that varieties of beans showing resistance to one strain of the pathogene may be susceptible to another strain of the same pathogene; that is to say, "there is a distinct difference between cultures of anthracnose obtained from diverse sources, in their power to infect the various varieties of beans." At the same time it was stated that "the writer has not found any varieties of *Phaseolus vulgaris* that have been resistant to every strain of the bean anthracnose fungus tested."

At the present time there are a few varieties that have shown considerable resistance to anthracnose but none are more promising than a strain of Red Kidney which has been under observation for three seasons. It has shown thus far a high degree of resistance to anthracnose when inoculated with the fungus under artificial conditions, as well as when grown in the field under natural conditions favorable to the extensive development of the disease and when, indeed, the common strain of Red Kidney became so badly infected as to be practically worthless.

The attention of the writer was first called to this strain in 1913 by Mr. John Q. Wells of Shortsville, New York, who had been searching for some clean Red Kidney seed in order to test the clean seed method of controlling anthracnose. This strain secured by Mr. Wells was originally selected by Mr. Byron Luce of Marion, New York, eleven or twelve years ago. Mr. Luce found a single plant standing up alone, the only healthy one in the field. Several years passed before Mr. Luce and his brothers had enough seed to plant their own fields. Mr. Luce sold his interest in the farm and his nephew and a few neighbors are now growing this strain. They have made no effort to disseminate it, so that now not more than fifty acres are grown in that section this year. In 1912 these beans were said to pick[2] but two pounds out of a bushel while common

[1] Barrus, Mortier F. Variation of varieties of beans in their susceptibility to anthracnose. Phytopath. **1:** 190–195. Pl. XXIX. 1911.

[2] "Picking" a certain number of pounds is a term used commonly by farmers and buyers to mean the number of pounds of poor beans picked out of a bushel. In the case mentioned the large pick was due mostly to the large number of spotted seed.

Red Kidneys grown beside them, planted at the same time, and treated alike, picked thirty pounds.

Mr. Wells sent the writer some of this seed which he called a blight resistant strain and wished to have it tested for resistance. It was then included in the variety tests for resistance to anthracnose. The first inoculation of this strain was made August 3, 1913 on seedlings grown in the greenhouse with strain F of *Colletotrichum lindemuthianum*. An examination on August 17, showed results recorded as follows: Of 19 plants inoculated, 4 showed fair[3] infection, 14 slight, and 1 no infection. Susceptible varieties inoculated at the same time under similar conditions gave good to excellent infection. No plants of the common strain of Red Kidney were inoculated at this time but previous inoculations had shown it to be susceptible to this strain of the pathogene. Subsequent inoculations with this and other strains of the organism made on seedlings grown in the greenhouse about the age of the potted plants shown in figure 1 are given in the following tables. The results secured from inoculations made at the same time on the ordinary strain of Red Kidney or on other varieties are included for comparison. For convenience the resistant strain has been designated Wells' Red Kidney.

For the purpose of obtaining illustrations the resistant and common strain of Red Kidney were grown in the same pot, inoculated at the same time with various strains of the pathogene, and after infection had shown up well, one pot, showing results secured from each strain represented, was photographed. An explanation of the results secured will be found in the explanation of the several figures. In each case the plants of the resistant strain became but slightly or not at all infected while those of the common strain were destroyed.

In order to ascertain whether Red Kidney beans in other localities might show resistance, seed was obtained in 1915 from seedsmen in Boston and Marblehead, Massachusetts, Bristol and Philadelphia, Pennsylvania, Chicago, Illinois, New York City, and points in Yates, Ontario, Monroe, and Seneca counties, New York. Four samples of the resistant strain were obtained from different localities. Two plantings were made in the greenhouse and one in the garden, and inoculated with a mixture of strains

[3] Degrees of infection expressed as follows:

Excellent—Plant destroyed.

Good—Abundant lesions. Plant does not die but is so badly affected that it could not produce a crop.

Fair—Several lesions well defined, but plant enabled to live and produce a fair crop.

Slight—Few lesions, but apparently not affecting growth of plant.

Very slight—Very small, scarcely distinguishable lesions present.

None—No lesions observed on any part of plant.

TABLE I

Showing results secured on varieties of beans from inoculations with cultures of Colletotrichum lindemuthianum under conditions favorable for infection

STRAIN OF PATHOGENE	DATE OF INOCULATION	DATE OF INSPECTION	VARIETY	NUMBER INOCULATED	NUMBER INFECTED	DEGREE OF INFECTION[3]
A	Dec. 7, 1913	Dec. 22, 1913	Currie Rust Proof	13	13	Excellent.
			Wells' Red Kidney	7	2	2 slight, 5 none.
			Round Six Weeks	13	13	Excellent.
			Kentucky Wonder Wax	10	10	Excellent.
			White Prolific	14	14	Excellent.
B	Dec. 20, 1913	Dec. 28, 1913	Hodson Wax	18	18	Excellent.
			Common Red Kidney	14	14	8 fair to good, 6 affected at base of stem only.
			Wells' Red Kidney	15	2	2 slight, 13 none. Later there were indications of lesions but nothing appeared that would injure the plant.
			Childs' Horticultural	17	17	Excellent.
Mixture of A & N	Jan. 16, 1915		Detroit	8	8	Good.
			Wells' Red Kidney	8	8	Slight.
			Rust Proof Intermediate Horticultural	9	9	Good.

A, F, K, and N of *Collectotrichum lindemuthianum*. In tables II and III are shown the results secured from these inoculations.

The vines of Wells' Red Kidney stood up well and, in the garden, produced well-filled clean pods in comparison with the others which did not need artificial inoculation as early in August they were badly infested.

This resistant Red Kidney seems to be a distinct strain. Not enough careful notes have been taken to give a description of the difference in the appearance of the vines between this strain and the common one, but there is a recognizable distinction. The seeds are a lighter red color and have a clean bright appearance in bulk. Some dealers have expressed themselves as believing this lighter color to be detrimental to their sale while others say that it is not.

TABLE II

Showing results secured in greenhouse on seedlings of two plantings of Red Kidney beans, inoculated with strains A, F, K, and N of Colletotrichum lindemuthianum

VARIETY	NUMBER OF PLANTS INOCULATED	NUMBER OF PLANTS INFECTED	DEGREE OF INFECTION				
Wells' Red Kidney from 4 localities	60	30		5 good	5 fair	20 slight or very slight	30 none
	59	59	5 excellent	8 good	34 fair	12 slight or very slight	
Common Red Kidney from 10 localities	117	115	98 excellent	15 good	1 fair	1 slight	2 none
	140	138	43 excellent	71 good	18 fair	6 slight	2 none

TABLE III

Showing results obtained in pods and seeds from growing Red Kidney beans, secured from various sources, in disease garden, where they were exposed to natural infection and in addition the resistant strain was inoculated on August 21, 1915 with a mixture of strains A, F, K, and N of Colletotrichum lindemuthianum under conditions favorable for infection.

STRAIN	NUMBER OF PLANTS	NUMBER OF PODS PRODUCED	NUMBER OF PODS INFECTED	DEGREE OF INFECTION	GRAMS OF SEED	
					Good	Cull
Wells' Red Kidney from four localities	109	901	73[1]	Slight to fair	1748	132
Common Red Kidney from nine localities	223	1121	1093[2]	Good to excellent	593	339

[1] These pods came from 15 plants.

[2] The 28 anthracnose-free pods came from 3 plants.

In the fall of 1913, the writer visited Mr. Wells who wished him to observe the difference in appearance between the resistant and the common strain growing in adjoining fields on his farm. The common strain was very badly infested and the pick from it must have been considerable, but a careful examination of the resistant strain showed a remarkable freedom from the disease. Since then Mr. Wells has been growing only the resistant strain. What seed he had for sale was sold to farmers in Ontario, Yates, Monroe, Orleans, Wyoming, Seneca, and Tompkins counties, New York. He estimated that at least two hundred acres of beans from this seed had been grown this year, and that the yield should be at least four thousand bushels. Most of this stock will not go on the general market, but will be saved for seed purposes.

An opportunity was given the writer to examine many of these fields and the beans were found in every case to stand up well and to be comparatively free from anthracnose. It is true that now and then an infected plant could be found, but the loss was practically nothing. Several fields were planted in part to Wells' Red Kidney and the remainder to the common strain. Even early in August the two strains in such fields could be distinguished at a distance because vines of the resistant strain covered the ground while those of the other strain were already so badly affected that they did not nearly occupy the ground. In fact, the planting of the resistant kind or of the ordinary kind meant the difference, this year, between a profitable and an unprofitable crop.

The season of 1915 has been exceptionally favorable for the development of most parasitic fungi and bean anthracnose has been epiphytotic throughout the state especially on the variety Red Kidney. It has been, therefore, a very satisfactory year to test, under natural field conditions, the resistance of this strain of Red Kidney to this disease. It has fully come up to the highest expectations of those who are interested in it. It may be true that some strain of the anthracnose fungus not yet used for inoculation, may be able to bring about an infection. But as long as it can be grown and remain as free from anthracnose as it has been in the past, it is the most satisfactory Red Kidney bean to grow. It should be tested in other sections where this variety is commonly grown.

Badly affected plants among the resistant ones probably represent impurities in the seed for no great amount of effort has been made in the past to keep them pure. Crosses may have taken place between these beans and the common kind growing in adjoining rows. An effort is being made by a few farmers who are growing no other kind of bean than this strain to eliminate mixtures or any plants showing susceptibility to anthracnose by roguing the field carefully. As an additional precaution it may be advisable to select the most desirable plants in the field for planting a seed plot to be maintained each year.

Wells' Red Kidney is not resistant to bacterial blight caused by *Bacterium Phaseoli*, to brown rot caused by *Sclerotinia libertiana*, or to the root rots common in some parts of New York. Bacterial blight is seldom a serious disease here. The brown rot occurs only during exceptionally wet seasons on beans whose vines cover the ground and even then does comparatively little damage. The root rots are very troublesome in some localities and as yet little is known regarding their control. Anthracnose has been responsible for the enormous loss to beans this year, but it is hoped that the new strain will enable growers of Red Kidney beans to avoid further loss from this disease.

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Fig. 1. 88a, Wells' Red Kidney. 88, common Red Kidney planted in same pot in greenhouse, inoculated March 2, 1915, with strain A of Colletotrichum lindemuthianum under conditions favorable for infection. Photograph made March 12. This strain of the organism has never procured infection on common Red Kidney.

Fig. 2. 88a and 88 planted in the same pot in greenhouse, inoculated March 2, 1915, with strain F of Colletotrichum lindemuthianum, and photographed March 12. On 88, excellent infection occurred. One plant of 88a showed fair infection and an occasional lesion could be found on the others.

Fig. 3. 88a and 88 planted in same pot in greenhouse, inoculated March 2, 1915 with strain K of Colletotrichum lindemuthianum. Photograph made March 14. 88 showed excellent infection while 88a showed only slight lesions on the three plants.

Fig. 4. 88 and 88a planted in same pot in greenhouse, inoculated April 3, 1915, with a mixture of strains A, F, and K, of Colletotrichum lindemuthianum. Photograph made April 12. 88 showed excellent infection while 88a showed 1 with fair, 1 with slight, and 2 with no infection.

FIRE BLIGHT ON CHERRIES

J. W. Hotson

With Plate XIV

During 1914 and 1915 a great deal of damage was done to the orchards of the Yakima Valley by fire blight caused by *Bacillus amylovorus*. This disease has been known in the Valley since 1905 and probably existed here some time before that date but, partly through ignorance of the character of the disease and partly through a fear of depreciating the value of property, the presence of fire blight was kept quiet for about seven years. During these years the disease gradually became more and more prevalent, finally becoming so thoroughly established that it required drastic methods even to hold it in check. Although the apples and pears were the principal trees affected, yet not infrequently it was found on the quince, prune, crab, and Yakimine.

During the spring and early summer of 1915 there was a noticeable increase in the number of fruit infections. Frequently a number of infected pears or apples might be found on trees where there was very little twig or body infection present. About the middle of June when the cherries were beginning to ripen the writer's attention was drawn to a peculiar condition of the fruit on Royal Ann cherry trees near Selah, Washington. On examination two trees were found to be affected, one a large tree about eight or ten years old and well loaded with fruit. The other, which was located close to the former, was a small three-years-old Royal Ann with only a few cherries on it. At the time these trees were first examined by the writer about one-third of the fruit on the larger tree was affected.

The cherry disease first appears as small depressions in the surface of the fruit. These are usually few in number at first but eventually occur practically all over the surface, gradually decreasing the size of the cherry and giving it a shrunken, wilted appearance. In figure 1 of Plate XIV is shown a branch with affected fruits and a few cherries not diseased. The relative size of the diseased and sound cherries as well as the general wilted, wrinkled condition of the former may also be seen in this figure. This same condition is illustrated also in figures 2 and 3, the former being only slightly affected while the latter represents a more advanced stage of the disease. In some instances, as shown in figures 4 and 5, small

amber-colored, sticky beads are produced, resembling very strongly the exudation of fire blight. As far as has been observed this trouble is confined entirely to the fruit, giving no evidence of disease on the twigs or leaves.

In order to determine definitely and conclusively whether or not this exudate was the result of *Bacillus amylovorus* a number of careful experiments were carried on. A preliminary examination with the compound microscope showed abundance of bacilli resembling this organism.

In making the gross cultures on pears the following method was adopted: White granite dishes eight inches in diameter and two and one-half inches deep were washed, sterilized in corrosive sublimate (1 to 1000) and then rinsed in sterile water. Panes of glass (10 inches by 12 inches), which were used as covers, and the green pears, on which tests were made, were treated in a similar way. Care was also taken to select pears for these experiments from trees not infected with fire blight. These precautions were taken in order to eliminate as far as possible all chances of contamination. The pears after being treated were cut in half with a sterilized knife and three or four halves were placed in each granite dish with sufficient sterile water to cover the bottom but not enough to reach to the cut surface of the pears. One half-pear in each dish was always left as a control, the others were inoculated from the beads of exudate occurring on the fruit of the cherry, each dish then being covered with a pane of glass. All of these inoculations produced the characteristic milk-white beads such as are found when the fire blight organism is treated in a similar way. In figure 8 of Plate XIV is shown the result of an inoculation directly from the exudate on the cherry to sterilized pears. Gross cultures were also made from the flesh taken just beneath the skin of wilted cherries which were apparently affected but did not show any exudate. Many of these did not produce the blight organism although some did. The organisms thus obtained on the sterilized pears were inoculated into the young, rapidly growing shoots of a Bartlett pear. This tree is shown in figure 6 with the two twig infections at *a* and *b*. The former which is a typical terminal infection of fire blight is reproduced on a larger scale in figure 7. The stems and leaves have turned black showing the characteristic scorched appearance.

From the gross cultures on pears inoculations were also made on the fruit and twigs of Royal Ann and Bing cherries while still attached to the tree. In some instances the fruit was punctured with a fine needle while in others the organism was smeared over the surface of the cherry. The infected fruit was protected from the direct sunlight by cloths. Four days after inoculation the punctured cherries began to show evidence of infection. They became depressed and began to dry in the region of

inoculation. In seven days small beads of exudate began to appear over the surface of the fruit. This exudate was inoculated into pear twigs and also upon sterilized pears as already described. In both these cases the typical fire blight reaction was obtained.

In order to more clearly demonstrate that the organism producing this "cherry blight" is identical with that producing fire blight, exudate was taken from an infected cherry and inoculated directly into the twig of a pear tree and also on Bing and Royal Ann cherries. The results were the same as those previously obtained. A large number of gross cultures of the fruit of cherries was also made in the laboratory. These were arranged with the same care and precaution as in the case of the pears. In the majority of these cases typical exudate was obtained but as time went on only ripe cherries could be obtained for experimentation and these would either crack and become contaminated in the moist chambers or begin to decay before results could be obtained. Of the cherries inoculated while still on the tree over ninety per cent. showed unmistakable evidence of fire blight infection.

The organism producing this disease was also plated out in the usual manner and pure cultures obtained both from the exudate found on the original infected fruit and also from the flesh just beneath the skin. Both of these cultures produced the characteristic reaction of fire blight when inoculated on the sterilized cut pears in the laboratory and pear twigs in the field.

One other experiment was tried in connection with this disease. The organism of fire blight obtained from the exudate from apple and pear trees was inoculated into the Royal Ann and Bing cherries. A majority of these cases where punctures were made proved successful.

In general, artificial infections were readily produced whenever the fruit was punctured. As many as half a dozen or more depressions, each probably representing a point of infection, were found on single cherries. It is highly improbable that all of these inoculations could be made at punctures. In some cases minute punctures have been observed but in the large majority of instances no evidence of a wound could be seen. The cherry season has been too short to determine definitely by experiment whether a puncture is absolutely necessary to insure infection, but some evidence has been obtained that points to a possibility of inoculation without a puncture of the skin. For example on June 21, Royal Ann cherries while still on the tree were smeared with cherry blight exudate, care being taken not to injure the skin. On July 12, just three weeks later, some of these cherries showed small depressions on the surface similar to those originally infected and when placed on sterilized cut pears produced the typical fire blight exudate. The short cherry season prevented fol-

lowing up this suggestion to determine to what extent cherries are so infected. It is quite possible that these particular samples had minute punctures at the beginning although none could be detected with a hand lens. Further work, however, is planned for another year in order to clear up this and other points.

These experiments clearly show that the organism producing the fire blight (*B. amylovorus*), which is so destructive to pears and apples, has also adapted itself to live on the fruit of cherries. It is possible, in fact entirely probable, that under favorable conditions this organism may acquire increased pathogenicity toward this host and attack the tissues as it does in the apple and pear.

The damage done by this cherry blight is as yet comparatively slight, but there are possibilities of it proving a serious menace to cherry culture. Growers should therefore be on their guard lest this phase of fire blight be allowed to gain a strong foot-hold and require drastic action in order to eradicate it, such as has happened in the Yakima Valley with the same disease on the apples and pears.

The writer is indebted to Miss Alice Montgomery, Bacteriologist of the Health Department of North Yakima, for plating the organism and obtaining pure cultures of it; also to Mr. Henry Schmitz and Mr. C. E. York for taking the photographs.

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EXPLANATION OF PLATE XIV

FIG. 1. A branch from a Royal Ann cherry tree showing sound and blighted cherries.

FIG. 2. Royal Ann cherry slightly affected.

FIG. 3. Royal Ann cherries showing a more advanced stage of the disease.

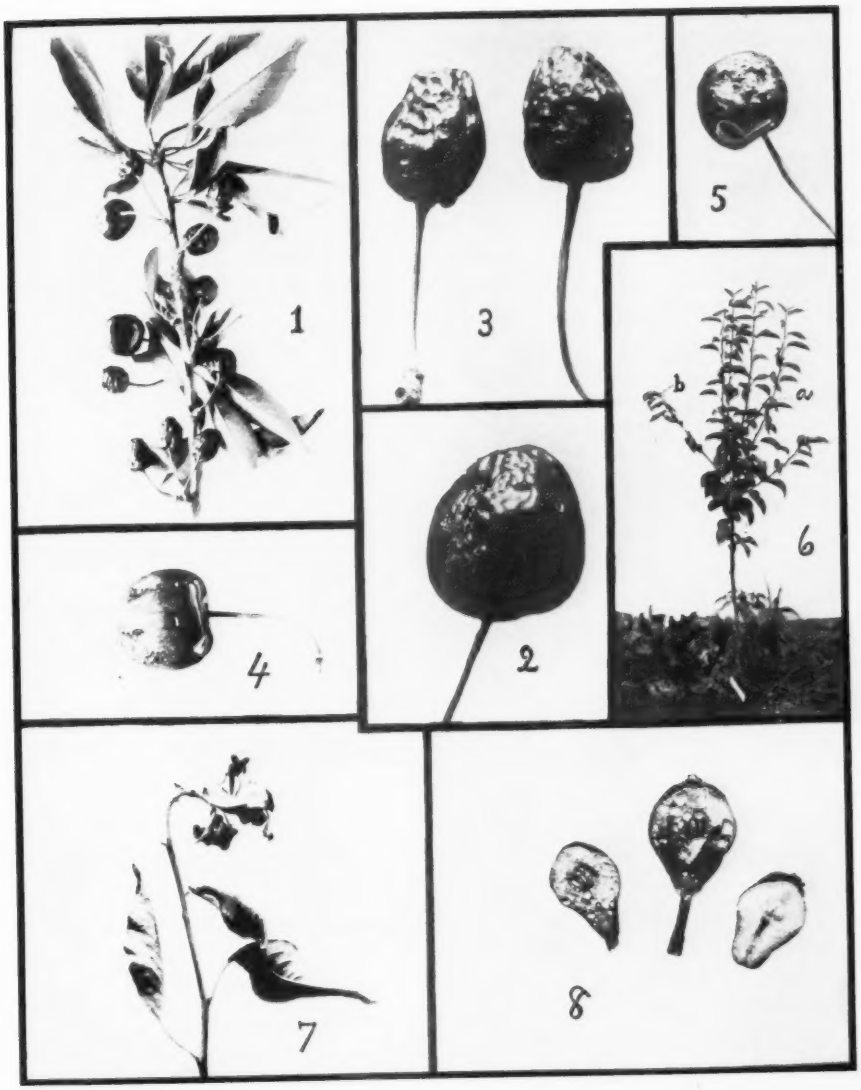
FIG. 4. Shows exudate on a Royal Ann cherry.

FIG. 5. Shows exudate on a Bing cherry.

FIG. 6. A Bartlett pear tree showing blighted twigs at *a* and *b*, the result of inoculation with the cherry blight organism.

FIG. 7. An enlarged view of figure 6, *a*.

FIG. 8. Gross culture of the cherry blight organism on sterilized cut pears.



HOTSON: FIRE BLIGHT ON CHERRIES

PYTHIACYSTIS INFECTION OF DECIDUOUS NURSERY STOCK

ELIZABETH H. SMITH

WITH FOUR FIGURES IN THE TEXT

The condition in question was first brought to our attention in March, 1914, by H. P. Stabler, Horticultural Commissioner of Sutter County, California, who summoned Prof. R. E. Smith to investigate a case of dying back and gumming of peach nursery stock. As the condition seemed to be general, the matter was turned over to the writer for investigation.

The bark of the affected trees was cankered chiefly above the bud, and in rare cases where the root stock was involved the infection was found to occur by spreading down from above rather than by initial infection at this point. In advanced cases the trunk was completely girdled at about two to six inches above the graft, with the trunk above entirely dead from the combined constriction and infection. In others from one to several smaller cankers occurred, showing as dark, more or less sunken spots, indefinite in outline, often bounded to some extent by the slightly raised concentric lines characteristic of other bark cankers. In the peach the extent of the disease was more clearly seen by removing the outer bark, which revealed a discolored gummy condition of affected spots, while the healthy tissue was white and clean. Pockets of gum often occurred between bark and wood, the gum finally accumulating in masses on the outside. The cankers before girdling averaged three to four inches in length.

The first cultures of Pythiacystis were isolated from the Stabler peach material, by inoculating standard agar tubes with a bit of the inner bark or wood from the margin of a canker. The outer bark was first washed with corrosive sublimate and removed with sterile scalpels. Most of the cultures, made in several media, were overrun with yeast, but after ten days an apparently pure growth of a nonseptate fungus was observed in one agar tube. The growth was about three-quarter inch wide about the bit of bark used for inoculation. This later developed sporangia typical of *Pythiacystis citrophthora*,[1] which discharged swarm spores in the characteristic manner.

During March and April of 1914 the same fungus was isolated from almond and pear trees which had been planted the fall previously. The

[1] Smith and Smith. A new fungus of economic importance. Bot. Gaz. **42**: 215–221. Sept. 1906.

appearance of the cankers on almond was similar to those on peach. On pear the spread of the disease was very rapid, and when observed the bark was often entirely black from the union for about a foot up the trunk. In March, 1915, the same organism was secured, in the manner described, from plum and almond.

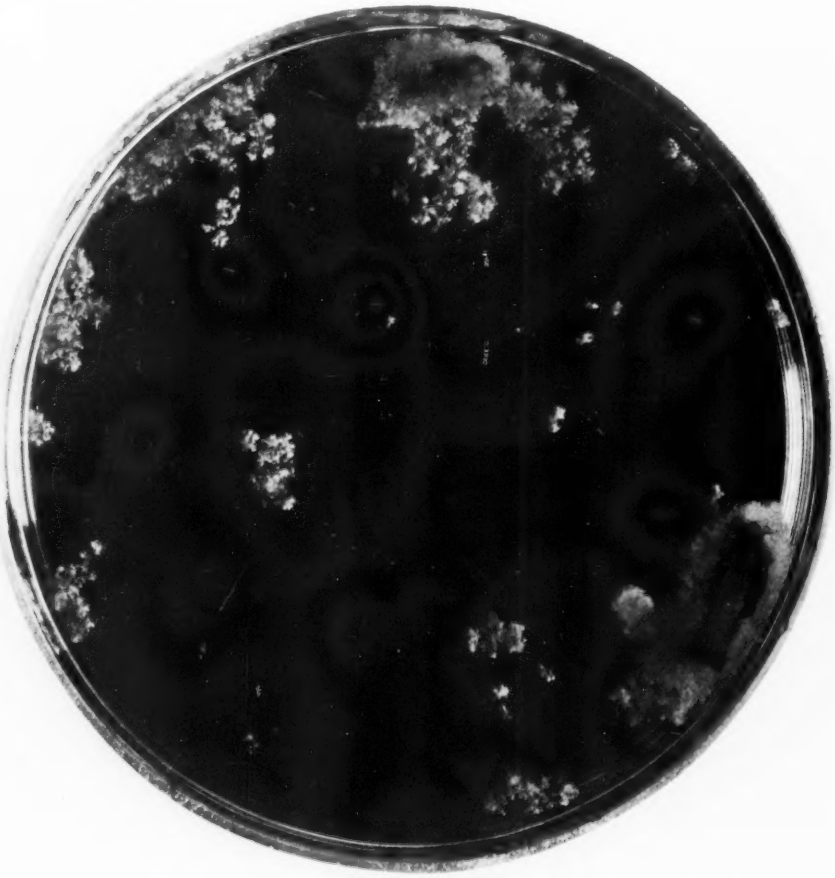


FIG. 1. The fungus in initial dilute prune culture from almond canker.

Of all isolations of the fungus secured, that from almond in 1915 was most satisfactory on account of abundance of material. After securing the fungus from the first specimens submitted, twenty trees from the same orchard were tested for Pythiacystis, from eight of which the fungus developed, in some cases in all of (fig. 1) the several cultures made from each tree. In all, the organism has been isolated in eight sets of material

from different points of the Sacramento Valley, and from eight out of twenty trees in the one case just mentioned.

In the winter of 1914–15 successful inoculations from pure cultures of the fungus into potted nursery trees were made as follows:[2]

1. December 8. Peach strain into apple (Winter Banana and Spitzenburg).
2. December 18. Peach strain into pear, fungus recovered.
3. December 23. Peach strain into pear, 2 trees.
4. December 30. Lemon strain into pear, fungus recovered.
5. January 26. Peach strain into peach (Muir), fungus recovered.
6. January 28. Peach strain into almond, fungus recovered.
7. February 2. Peach strain into pear (Bartlett).
8. February 8. Peach strain into peach (Early Crawford).
9. February 16. Lemon strain into pear (Bartlett).
10. March 12. Plum strain into pear.
11. March 12. Peach into almond into wild peach (probably *P. Davidiana*).
12. March 12. Peach into almond into cherry (Royal Ann).

From all of these inoculations distinct cankers were formed, from one-half inch to one foot in length, while from the checks nothing developed. With one exception, this one inoculation having dried out for lack of moisture, all inoculations tried were successful.

The first inoculations were made by cutting a narrow tongue (about one-half inch long and one-quarter inch wide) in the bark eight or nine inches from the ground, after the surface had been thoroughly washed with mercuric chloride and sterile water. The check was cut in the same way, either on a separate tree or several inches above on the same trunk. A bit of the fungus was then placed in the incision between the bark and wood, both inoculation and check being then tightly bound with a thick wad of sterile cotton three or four inches wide. Both were then saturated with sterile water, and in some of the first cases covered with a glass cage made to fit tightly over the pot. The trees were kept by themselves on an open balcony three stories from the ground and many of the inoculations exposed to constant rain. The cotton was kept moist in all cases by rain, sterile water, or by covering. When the shape of the tree permitted about two feet of glass tubing an inch or two in diameter was forced down over the tree to the ground, one end being buried in the soil and the top plugged with dry sterile cotton. It was found that from the soil circumscribed

[2] In discussing this paper Professor Fawcett reports the successful inoculation of *P. citrophthora* into peach and apricot trees in connection with his work at Whittier, Calif.

by the tube end sufficient moisture evaporated to keep the lesion moist. If the tube could be forced down only part way on the trunk, the lower end was dry plugged and a bit of moist cotton included.

FIG. 2

FIG. 3

FIG. 4

FIG. 2. Tree No. 7, pear, inoculated with peach strain by needle puncture; after 20 days.

FIG. 3. Tree No. 4, pear, inoculated with lemon strain; after 12 days.

FIG. 4. Tree No. 9, pear, inoculated with lemon strain and left exposed; after 8 days. Note the callus forming at border.

In later cases inoculation was often by needle punctures. In No. 7, for instance, three needle punctures were made just above the bud and about one and one-half inches apart, into the two lower of which a small bit of mycelium was tucked. The upper puncture was used as a check. The covering tube was forced into the earth as described above, the upper

end reaching four inches above the check. The extent of infection could be seen plainly by the blackening of the bark and the development of the cankers was observed from day to day. Within six days the two cankers had merged with no development at check. When the experiment was abandoned after twenty days the combined canker was 8 inches long, involving the check and extending one and one-half inches down into the stock (fig. 2).

As noted in the above list an authentic strain of *Pythiacystis citrophthora* was used to inoculate pear trees in two instances with positive results. In case No. 4, two inoculations with check were made on one tree, the lesions were wrapped and the tree covered with a bell glass. January 12 cankers two and three inches in length and surrounding the trunk were formed at the inoculations, with nothing at check. January 19 the fungus was recovered in culture from the edge of one of these cankers (fig. 3). In case No. 9, February 16, inoculation was by needle puncture and was left without wrapping. February 24 a canker one inch long had developed, with nothing at check (fig. 4). It was raining February 16 to 20.

As in the case of Pythiacystis on lemon[3] the bark is affected almost uniformly through its entire thickness and remains firm, with no apparent fungous growth on its surface at any stage.

In all typical cases at about the time the cankers become inactive a callus forms, or rather a mealy puffing out of the bark cells as described by several workers under other conditions. A similar occurrence has been noted by the writer in connection with cankers from other causes. The swelling usually begins just beyond the lower point of the visible canker in the shape of a half-moon, and may appear at the upper margin, rarely at the sides.

Several attempts have been made to infect the Eureka lemon and other citrus stock with the peach strain of Pythiacystis but so far without success, probably on account of the lateness of the season when tried. Apparently infection is much more rapid under conditions of abundant moisture in deciduous than in citrus bark.[3] This experiment will be repeated another season.

During March of 1915 inoculations were made under ordinary conditions in the University nursery. The work was done during rainy weather and just after plowing, while large clods of turf and soil were still thrown up about the trees. Puncture inoculations only were made, with no wrapping. Check trees were punctured in each case. A tabulation follows:

[3] Fawcett, H. S. Two fungi as causal agents in gummosis of lemon trees in California. Mo. Bul. State Commission of Hort. **2**: no. 8. Also Phytopath. **3**: 194–195. 1913.

March 13. Peach strain into apricot, 3 trees; March 31, 1 positive.
Peach strain into almond, 3 trees; March 31, 1 positive.
March 31. Almond strain into almond, 3 trees; April 20, 2 positive.
Almond strain into apricot, 7 trees; April 20, 7 positive.
Peach strain into apricot, 5 trees; April 20, 5 positive.

The week following March 13 was very dry, but occasional rains followed until the middle of April. The March 13 cankers were very small, with considerable gumming. All inoculations of April 20 gave small but definite cankers one-half inch or more in diameter with copious gumming. Slight gumming occurred about three checks of April 20, otherwise nothing.

Attempts were made early in the season to inoculate trees at the crown by inoculating the soil about it, but without success. Our observations seem to show that most of our deciduous root stock is more or less immune to this trouble. The disease is probably spread to a large extent either in the nursery or in heeling in during the fall before planting. Our attention has been called to the trouble in the spring in every case, when growth fails to start, but the trouble at that time is always at an advanced stage.

So far as tried, no variety of deciduous fruit has failed to contract the disease after inoculation.

During the spring of 1914 a gumming almond tree was submitted, having two cankers about two and six inches above the bud and each about two inches in length, similar in appearance to the peach affection. The upper canker had completely surrounded the trunk.

From this an apparent Pythiacystis was isolated. In comparative work, however, it has been found to differ from the prevailing strain in:

(1) A greater rapidity of growth in culture,

(2) A much simplified branching of the mycelium as compared with the other strains,

(3) The ready production of oospores (in about three weeks' time) on agar media,

(4) In its failure to infect the pear after inoculation, though small cankers were obtained on the almond and the fungus recovered.

The study of this organism is as yet incomplete.[4]

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[4] Professor Fawcett (l.c.) has observed a similar strain in connection with his work on the lemon gummosis.

A PODOSPORIELLA DISEASE OF GERMINATING WHEAT

P. J. O'Gara

With Plates XV and XVI

While examining some wheat fields in the Salt Lake Valley during the summer of 1915 it was noted that there was a considerable unevenness of the stand, there being quite a proportion of very weak plants. Observations during the season of 1914 showed that these fields were infested by the wheat straw worm, *Isosoma grande* Riley, and it was at first supposed that the weakened plants had been injured by the larvae of this insect. Careful examination, however, did not reveal the presence of larvae in the unthrifty plants. The wheat plants in the fields mentioned were largely volunteer, although some additional seed had been sown in the fields. It is the practice of many of the wheat farmers in certain districts of the Salt Lake Valley to grow wheat successively in the same field by depending upon the volunteer stand, sometimes adding seed where it is believed that the volunteer stand will not be sufficient to produce a crop. Very often five or six crops are grown on the same tract without any other cultivation than that of discing and harrowing the land. Under such conditions a notable increase in insect infestation and fungous injury to the growing crops is found.

A large number of weakened plants were carefully removed from the soil and taken to the laboratory where it was found that the attacked wheat kernels were infected with a fungus which had apparently destroyed their contents at or near the time of germination. Sections of the diseased kernels indicated that the contents of the kernels had been completely disorganized and the interior occupied by a dark brown septate mycelium. There was no apparent external mycelium covering the grain but the stalks of the fungus, which were often five or six in number, had grown out from the internal mycelium. Pure cultures of the organism were made and it was found that the fruiting was typical in every respect, excepting on nutrient agar or on cultures which tended to become dry too readily. The best culture media were found to be wheat and rice on which the fruiting was always typical. On nutrient agar no stalks were produced and the conidia were formed directly on the mycelium. The mycelium is at first hyaline and later becomes dark brown. Fruiting takes place within two weeks in practically all cases.

The fungus has been found only on the kernels of germinating wheat and has never been found attacking the growing portions of the plant. The fungus is not considered parasitic, since it seems to attack the wheat kernel at or about the time of germination, completely destroying the contents. The wheat seedling is permanently dwarfed and produces few stools by reason of the fact that the proper food supply is wanting in the early stages of growth on account of the total destruction of the contents of the kernel. As a rule these plants seem never to recover, though growing under favorable conditions.

This paper is merely preliminary to one which will be prepared for publication later. Enough work has been done, however, to indicate that the organism causing this injury to germinating wheat is of considerable economic importance.

A search of the literature indicates, in so far as the writer has been able to determine, that this disease has not heretofore been noted and that the organism has not previously been described. As will be seen by the appended description, the fungus clearly belongs to the Stilbaceae and unquestionably belongs to the genus Podosporiella. There is in literature only one other species of Podosporiella, namely, *P. humilis*, Ell. & Ev., occurring on the foliage of *Garrya veatchii* in California. The specific name *verticillata* is therefore proposed for this organism and a description appended.

Podosporiella verticillata sp. nov.

Mycelium septate, at first white or hyaline, finally becoming brown to dark brown, producing practically no growth external to the wheat kernel, being wholly within the epidermal covering.

Synnemata parenchyma-like (not fibrous), arising from the mycelium within the wheat kernel, 1 to 5 millimeters long by one-fourth to one-half millimeter in diameter, straight or curved, infrequently branched above, cylindrical, rounded at the apex, at first smooth, olivaceous, lighter colored to hyaline at the apex; hyaline within; finally turning brown or black without but remaining hyaline within, producing conidiophores over the entire surface.

Conidiophores straight, irregular or slightly curved, 6 to 10 septate, 250 to 325 by 7 to 8μ; apical cell, hyaline, slightly inflated, 8 to 9μ in diameter, bearing conidia singly or in a single whorl up to 6 in number.

Conidia very variable, spindle or club-shaped, broader toward the base, straight or slightly curved, rounded at the ends, brown, both end-cells shading from brown to light brown or hyaline, 5 to 10 septate; 58 to 130 by 11 to 15μ.

Habitat in the kernels of germinating wheat, Salt Lake Valley, Utah, U. S. A.

Latin diagnosis. *Mycelio* in semenibus *Tritici vulgari*, epidermide tectis, rarius in superficie vigentis, septatis, primum albis vel hyalinis, deinde brunneis. *Stipitibus* erumpentibus, cellulosis (nec fibrosis), mycelio orientibus, 1–5 mm. alt. x $\frac{1}{4}$–$\frac{1}{2}$ mm. diam., rectis vel curvulis, superne infrequenter bifurcatis, cylindraceis, apice rotundatis; primum glabris, olivaceis, apice leniter coloratis vel hyalinis, deinde externe brunneis vel atris sed intus hyalinis; ubique conidiophores gerentibus. *Conidiophoris* rectis, irregularibus vel leniter curvulatis, 6–10 septatis, 250–325 x 7–8μ, cellula apice hyalina, leniter incrassata, 8–9μ diam., conidium unicum vel ad 6-verticillatim gerentis. *Conidiis* multo variabilis, fusiformibus vel clavatis, basi crassiusculis, utrinque rotundatis, brunneis, 5–10 septatis, 58–130 x 11–15μ, loculis extimis apice brunneis vel pallide brunneis vel hyalinis.

Hab. in semenibus germinantibus *Tritici vulgari*, Salt Lake Valley, Utah, Am. bor.

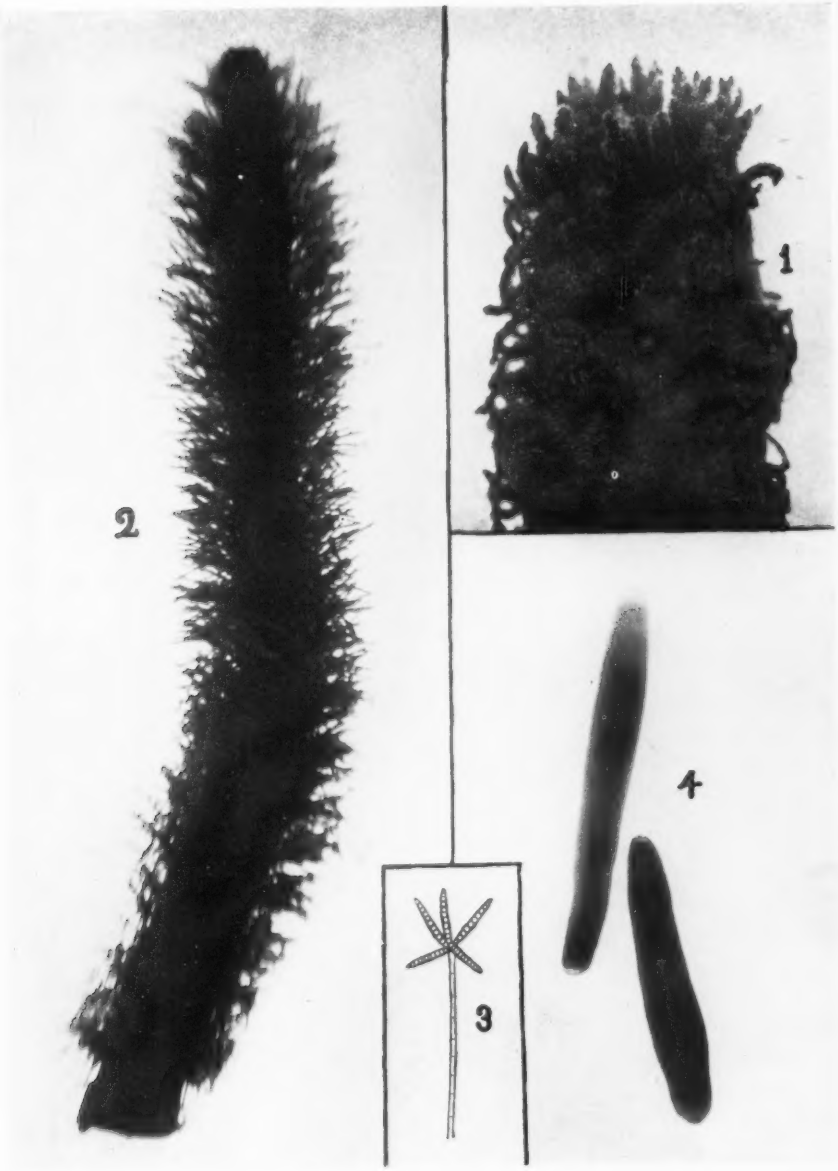
DEPARTMENT OF AGRICULTURAL INVESTIGATIONS
AMERICAN SMELTING & REFINING COMPANY
SALT LAKE CITY, UTAH

EXPLANATION OF PLATE XV

FIGS. 1 and 2. Wheat plants showing fruiting synnemata or stalks of *Podosporiella verticillata* growing from attacked grains. Natural infection, collected April 13, 1915. Magnified 4 diameters.

FIGS. 3 and 4. Wheat grains completely destroyed by *Podosporiella verticillata*. These show very little germination. In figure 3 the wheat grain has been split open lengthwise to show total destruction of contents. The several synnemata were stripped of conidiophores and conidia in removing the kernel from the soil. Natural infection, magnified 4 diameters.

FIG. 5. Pure culture of *Podosporiella verticillata* on nutrient neutral agar, two weeks old. Conidia produced directly from mycelium. No synnemata formed.



O'Gara: Podosporiella verticillata

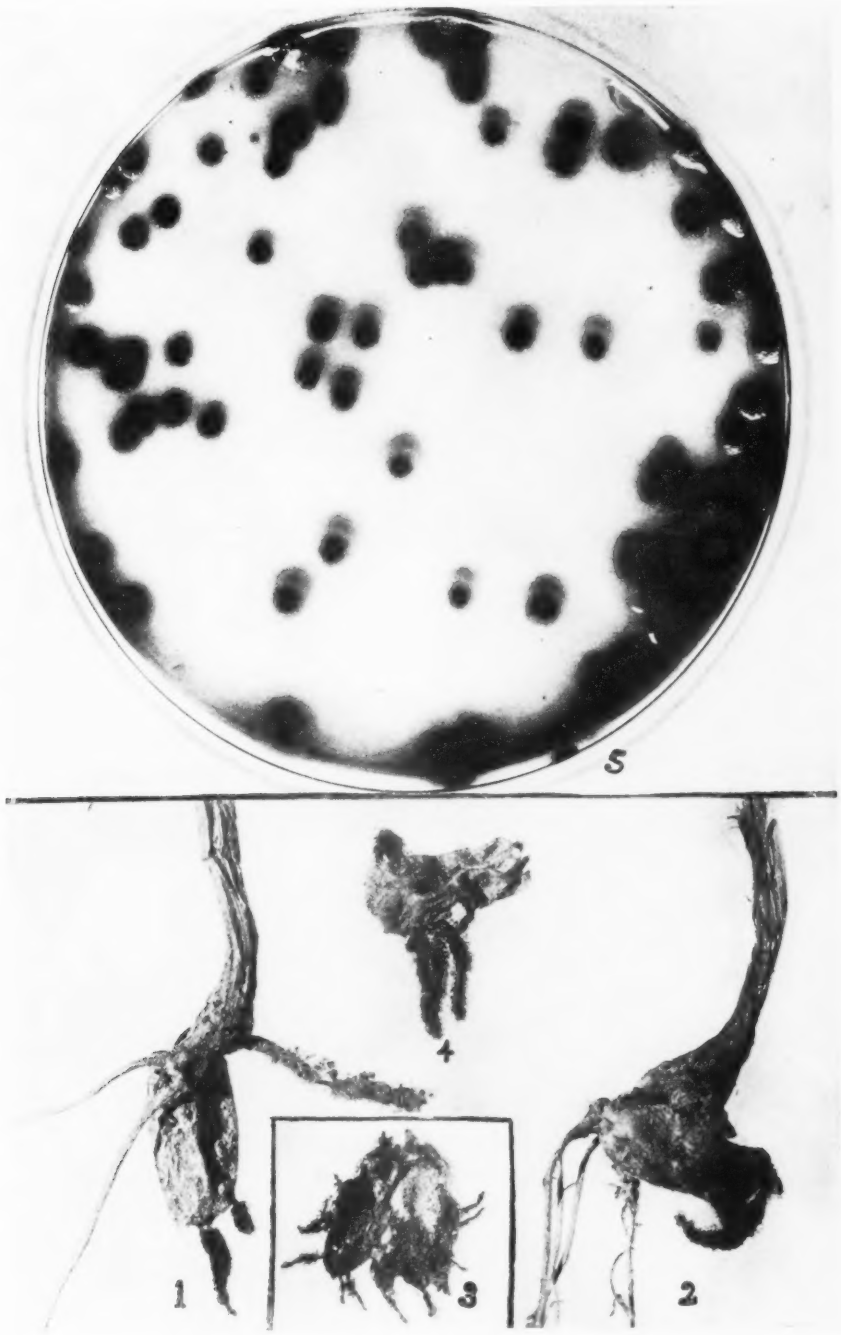
Explanation of Plate XVI

Fig. 1. Synnemata of *Podosporiella verticillata* growing on rice. Photograph of upper part of rice tube, magnified 2½ diameters.

Fig. 2. Synnemata or stalk taken from rice culture shown in figure 1. Conidia dropped from the conidiophores in preparation of specimen for photographing. Photomicrograph, magnified 45 diameters.

Fig. 3. Conidiophore with whorl of five conidia attached to apical cell. (Drawing, somewhat diagrammatic).

Fig. 4. Two conidia, from rice culture of figure 1. Septa not shown in photograph due to dark brown color of walls and contents. Photomicrograph, magnified 425 diameters.



O'Gara: Podosporiella verticillata

NOTES ON THE FIRE BLIGHT DISEASE

V. B. Stewart

Fire blight as influenced by commercial fertilizers

It is the general opinion that cultivation and the application of nitrogenous fertilizer or of any material that tends to induce rapid and succulent growth, favor the serious development of the fire blight disease. The experiments conducted by the writer[1] show that although young pear trees growing in sod are susceptible to fire blight and may become infected, they are, on the other hand, less liable to attack by the blight bacteria than trees which have been manured and well cultivated. The application of commercial fertilizers to certain soils undoubtedly favors the fire blight disease by increasing the succulence of the trees. On the other hand, there is no evidence to show that the fertilizers influence the blight when applied to well tilled soil which already has sufficient amounts of the necessary plant food constituents to insure a good growth of the trees. Does the presence of excessive amounts of the various chemical compounds in the soil cause a physiological change in the tissues which tends to break down the resistance of the tree to blight? With this question in mind an experiment was conducted on nursery ground from the spring of 1911 until the autumn of 1914. The soil was clay loam and had been under cultivation for several years. No commercial fertilizers had been applied, but in the spring of 1909 an application of stable manure was made when the ground was planted to rose stocks. The roses, which made a good growth throughout the next two seasons, were dug in the autumn of 1910.

The ground for the experiment was divided into four plats fifty feet long by twenty feet wide. A space six feet in width separated each plat from the others and in each plat thirty French grown pear seedlings were planted.

The amounts of fertilizers recommended for pear trees at that time by Prof. U. P. Hedrick of the Geneva Agricultural Experiment Station were fifty pounds per acre of actual nitrogen, fifty pounds of phosphoric acid and one hundred pounds of potash. To secure these amounts per acre the following was suggested: Three hundred and fifty pounds of dried

[1] Stewart, V. B. The fire blight disease in nursery stock. New York (Cornell) Agr. Exp. Sta. Bul. 329: 347-350. 1913.

blood plus one hundred pounds of nitrate of soda to obtain the nitrogen; three hundred and fifty pounds of acid phosphate to obtain the phosphoric acid and two hundred pounds of muriate of potash to supply the potash.

The above constituents were applied as follows: To plat I nitrogen, at the rate of fifty pounds per acre; to plat II phosphoric acid, at the rate of fifty pounds per acre plus potash at the rate of one hundred pounds per acre; to plat III were applied nitrogen, phosphoric acid and potash at the rate of fifty, fifty and one hundred pounds per acre, respectively; to plat IV no fertilizers were added.

The fertilizers were applied in the spring at about the time the trees developed the first new leaves. The materials were spread over the plats and raked into the soil. No weeds were allowed to grow in any of the plats and all were cultivated three times during the summer.

In a few cases there was apparent injury to the trees due to the fertilizers applied, particularly in the nitrogen and phosphoric acid plats. This injury is attributed to poor distribution of the fertilizer in the soil, it being applied too closely to the trees. In the month of August all of the seedlings which had made a suitable growth were budded to Bartlett pears.

The following spring (1912) the seedlings were snagged (all of the growth was removed above the point in the trunk of the seedling at which the Bartlett bud was inserted the previous summer) and most of the buds started to grow, continuing their development throughout the season. No fertilizers were applied during the year 1912 but all the plats were cultivated four times that season.

Several of the trees were killed during the winter of 1912–1913 by low temperatures and others were girdled by rodents, however, there remained about twenty trees in each plat which were not injured. The fertilizers were again applied in the spring of 1913 to the different plats, the same amounts being used as in 1911. The trees were cultivated four times during the summer and all made a good growth, appearing to be somewhat larger and more succulent at the end of the season, than the average two-years-old budded pear stock in the nursery rows. But little difference could be noticed in the growth of the trees in the different plats except that those in the nitrogen plat were, on an average, slightly larger than the others.

The plats again received the same amounts of fertilizers in the spring of 1914 and were cultivated four times. On July 7 five trees in the central area of each plat were inoculated with a two-days-old bouillon culture of *Bacillus amylovorus* (Burr) Trev. The inoculations were made by immersing the point of a needle in the bouillon culture and pricking the tips of three young, tender shoots on each tree. Three days later many of the

infections were apparent at the tips of the shoots and within a period of five days all the inoculated shoots except one showed fire blight infections. No difference could be noticed as to resistance of the trees to blight in the different plats. The slight increase in growth of the trees in the nitrogen plat did not materially affect the blight. Also in this experiment, at least, there was no evidence to verify the opinion that the application of phosphates and potash tends to harden the tissue of the trees, making them more resistant to fire blight.

No attempt was made to remove the affected shoots and within the short period of three weeks most of the inoculated trees were ruined. The blight had extended down the branches to the trunks and girdled the trees causing their destruction. Many natural infections occurred after the inoculated shoots became diseased and practically none of the trees in any of the plats were free from blight on July 24. The trees appeared to be exceedingly succulent and the progress of the blight was very rapid. By August 20 all of the trees were ruined, those trees in the check plats being as susceptible to the disease as trees which had been fertilized.

During the four seasons that the above experiment was continued, the trees received a normal amount of precipitation each year, which, along with proper cultivation, afforded them ideal conditions for growth. Any marked effects on the trees caused by the application of the fertilizers should have been readily apparent. On the other hand, sufficient growth was made by the trees in the check plat to indicate that the fertilizers were not necessary additions to the soil in order to greatly influence the growth of the trees. Under such conditions the presence of the fertilizers in the soil had no apparent effect on the inherent qualities of the trees with respect to their resistance to the attacks of the fire blight bacteria.

Pears resistant to fire blight

Fire blight is known to be more destructive in certain varieties of pear trees than in others and within recent years particular mention has been made of several comparatively new varieties which have shown special resistance to the attacks of the fire blight bacteria. In most cases these varieties have practically no value commercially, however, certain horticulturists have suggested the possibility of using these pears for developing varieties that are immune to fire blight and which also possess good edible qualities. Investigations along this line have already been reported by Reimer[2] of California and Hansen[3] of South Dakota.

[2] Reimer, F. C. Blight resistance in pears and pear stocks. California Hort. Com. Mo. Bul. 4: 145–149. 1915.

[3] Hansen, N. E. Breeding pears immune to blight. South Dakota Agr. Exp. Sta. Bul. 159: 187–191. 1915.

With such pears that have not been affected by fire blight it is of interest to determine whether the trees are resistant to the disease owing to the characteristic growth of the tissue which checks the activities of the bacteria or whether they are really immune to fire blight by virtue of certain inherent qualities which prevent the bacteria from becoming established in the tissue of the trees. The greatest chance of obtaining a suitable pear that is resistant to blight is by crossing one of the standard commercial varieties with a pear that is known to be absolutely immune to the disease. The problem becomes more difficult when the crossing is done with a variety that is only resistant and not entirely immune. So far as is known no variety which has been thoroughly tested, has proved immune to the disease under all conditions.

The Douglass variety which originated as a seedling of the Kieffer pear, probably crossed with the Angoulême has received special attention as a resistant variety. According to the advertisements of A. H. Griesa, Lawrence, Kansas who originated the Douglass pear this variety has been growing in central Kansas for fourteen years and although fire blight has been very prevalent in that region the Douglass pear has never been known to blight. In order to test the resistance to blight of this pear, three two-years-old trees were planted in the disease garden at Ithaca, New York, in the spring of 1914. At this time Mr. Griesa also sent a tree of the variety Abraham which was planted near the Douglass trees.

In the autumn of 1914 Dr. F. A. Wolfe of the Alabama Polytechnic Institute asked the writer to test a variety of pear which appeared to be resistant to fire blight in Alabama. According to the pomologist of the United States Department of Agriculture, the variety originated as a seedling from the Japanese or Chinese Sand pear, *Pyrus sinensis*. Six two-years-old nursery trees of this variety were received in the spring of 1915 and planted near the Douglass pear trees mentioned above.

On May 1, 1915, the Douglas strees had developed numerous new shoots and there were present also several blossom clusters which were just opening. The shoots were about three to four inches in length and very succulent. The following inoculations were made with a three-days-old agar culture of *Bacillus amylovorus* isolated from an apple twig in the summer of 1914:

(1) A camel's hair brush moistened with water was smeared with the agar culture and then carefully brushed over the stigma and pistil of five blossoms. (2) The tissues of five other blossoms were pricked with a needle which had been dipped into the agar culture. (3) The tips of six Bartlett shoots and six Douglass shoots were inoculated by means of the needle smeared with the agar culture. (4) The tips of three Douglass shoots and three Bartlett shoots were injured with a sterile needle for checks on the inoculations.

On May 13 all of the inoculated blossoms were affected and the blight was extending down the pedicles. The extent of the lesions was slightly more marked in the tissue which had been injured than in the blossoms inoculated by means of the brush. Four of the inoculated Douglass shoots became diseased and five of the Bartlett shoots blighted; the infections had extended about three inches down the shoots. None of the twigs blighted which had been injured with a sterile needle.

Varietal inoculations were made May 26, 1915, with a two-days-old bouillon culture of *Bacillus amylovorus* isolated from apple in 1914. The new shoots on the trees at this date averaged about six inches in length and appeared to be relatively succulent. The following varieties were inoculated by pricking the tips of the shoots with a needle which had been dipped into the culture: five shoots on each of two Douglass trees; five shoots on one Abraham tree; three shoots on each of two Bartlett trees; three shoots on each of two Sand pear trees.

The first infections appeared June 23 but many of the inoculated shoots failed to blight at all. The progress of the blight in the affected shoots was slow and the damage slight, none of the trees was severely injured. Most of the infections dried up and did not extend down the shoots for a distance of more than three or four inches. This was particularly true of the Douglass trees. The failure of the infections to become destructive is attributed to the extremely dry weather which prevailed throughout May and June. The lack of precipitation impeded the growth of the young shoots which had developed, making the tissue hard and woody and more resistant to the activities of the blight bacteria.

On June 19 inoculations were again made with a two-days-old bouillon culture of *Bacillus amylovorus*. The growth of the trees still showed the effects of the dry weather but in general the shoots were fairly succulent and appeared to be suitable for inoculating. The new growth of the Sand Pear and Abraham trees was slightly more tender than that of the Bartlett and Douglass varieties. Several shoots on each of four Bartlett, one Abraham, four Sand Pear and three Douglass trees were inoculated.

On June 27 the first infections appeared and two days later several others were apparent, but some of the inoculated shoots never blighted. The progress of the blight in the affected twigs was slow and none of the trees was seriously damaged by the disease. On July 6 a few of the infections had extended down the shoots into the old wood, forming cankers two to three inches in length. These cankers were apparent on some of the trees of all varieties except the Douglass. The shoots of this variety were not affected so severely and the blight never reached the main branches of the trees.

In spite of the numerous small cankers formed none of the trees suffered to any extent and when observed July 25 new buds were developing from

points immediately below the affected areas. A sharp line of demarcation separated the healthy and blighted tissue.

The failure of the blight to severely affect the trees was attributed as in previous inoculations, to the dry weather throughout May and June which caused the trees to make a comparatively slow growth. Although there was heavy rainfall from June 30 to July 6 the effect of a large amount of precipitation on the growth of the trees was not apparent until the blight had run its course and all of the infections were dried out. Frequent observations were made throughout the season but none of the cankers became active again. An attempt to isolate the causal organism from two lesions on August 5 gave negative results.

On July 28 another series of inoculations were made with the same trees used in previous experiments. An average of four shoots were inoculated in each tree. Favored by the heavy precipitation which occurred during the month of July the trees were growing rapidly, many of the shoots being two to three feet in length. Six days after the inoculations were made the first infections appeared and in general the blight was more destructive than in all former inoculations. This was especially true of the Sand Pear trees; in practically every case the infections extended the entire length of the long tender shoots but the disease was not so destructive in the older branches. Numerous cankers were formed in the larger limbs and branches of the Bartlett and Abraham trees. The Douglass trees showed the greatest resistance. None of the shoots was entirely affected by the blight and its extent down the twigs was considerably less than in the other varieties. After August 20 there was a tendency for the tissues of all the varieties to harden and become more mature, thus checking the blight for the remainder of the season.

From the above inoculations it is apparent that none of the varieties tested are immune to fire blight. On the other hand the Douglass variety is affected less severely than the Bartlett trees or the young shoots of the Sand Pear trees. This, however, is attributed to the characteristic growth of the Douglass trees rather than to the presence of any inherent qualities which tend to make the trees immune. The young tender tissue of the Douglass variety is apparently as susceptible as of any other pear but the tendency for the tissue to rapidly harden, soon after it is formed, impedes the activities of the blight bacteria and the injury is less severe. The fact that the inoculations into blossoms gave one hundred per cent infection indicates that during a season favorable for blossom-blight, heavy losses might occur in a Douglass pear orchard owing to the destruction of the fruit by blossom-blight. It is well known also that fire blight cankers are not so destructive in the old limbs and branches of Sand Pears, however, the inoculations, along with the observations of certain

horticulturists, show that under ideal conditions for the disease, severe injury may occur to the new growth that develops during the season. The succulence of shoots which develop so rapidly makes them very susceptible to the blight. On the other hand the tissue hardens very rapidly and the older branches are therefore considerably more resistant to the disease.

With such varieties as the Douglass and Sand Pear, material is afforded for developing a suitable pear, that will have considerable resistance to fire blight, but the chances appear to be limited of producing a pear which is entirely immune.

It is of interest to note also that the results of the inoculation experiments discussed above are in accordance with the fire blight conditions which existed in New York State during the past season. Although an unusually severe epiphytotic of the disease occurred in 1914, the losses from blossom and twig-blight were comparatively small in 1915. This condition is attributed to the extremely dry weather which prevailed throughout the early part of the season of 1915; there was very little precipitation previous to July 1. The reduced water supply actually prevented a rapid growth of the trees in many cases with the result that the tissue was not so susceptible to the attacks of the fire blight bacteria. This point is well illustrated by the failure of infections produced artificially in the experimental trees, to become destructive. Also many of the hold-over cankers in blighted trees were less active on account of the dry weather and did not exude the gummy substance which is a source for new infections, especially blossom-blight, early in the season. After the middle of July, when there was an excessive rainfall for the remainder of the season, many of the cankers became more active and fire blight was much more prevalent.

Fire blight favored by a hail storm

The unusual prevalence of the fire blight disease in the orchards and nurseries of New York State throughout the summer of 1914 afforded an opportunity to observe the disease under many conditions. Of particular interest was an outbreak of fire blight in a two-years-old nursery block of Bartlett pear trees which being under high cultivation and favored by ideal growing conditions had made a rapid and succulent growth. On July 30 a severe hail storm occurred which caused considerable damage. Wherever the hailstones struck the pear trees the tender succulent bark was easily broken, producing small wounds in the tissue. The following day it was noticed that many insects of all kinds, especially flies, were attracted to these wounds to feed on the exuding sap.

An occasional infection of fire blight had been found in the pear trees previous to this time and in a nearby apple orchard twig blight was very common. On August 12, two weeks after the hailstorm, the injuries in the bark caused by the hailstones had begun to heal over to a considerable degree, but in many cases fire blight cankers were apparent on the trunks and branches of the trees. A large number of these blight infections appeared to have originated in the wounds of the bark made by the hailstones. All indications point to the fact that the blight bacteria were carried to the wounds by the insects which visited the trees to feed on the exuding sap. The injuries afforded the bacteria an entrance into the tissue and owing to the succulence of the trees the blight lesions developed very rapidly. Many of the trees were soon girdled and completely ruined.

A similar instance occurred also in a four-years-old pear orchard which had been well cultivated throughout the summer. This orchard which consisted of about fifteen hundred trees was also in the path of the hailstorm and approximately three miles distant from the nursery trees mentioned above. Previous to the storm considerable fire blight had appeared in a large apple and pear orchard nearby but only very little blight had been noticed in the four-years-old pear trees. On the other hand several days after the hail storm numerous infections of fire blight were apparent on the trunks and limbs of these small trees and in many cases it was evident that the infections originated at the points of injury in the bark made by the hailstones. Most of the trees were saved from destruction by removing the affected branches but where infections occurred on the trunks of the trees the eradication of the disease was more difficult. About sixty of the trees were girdled and ruined by fire blight cankers which developed around wounds in the bark produced by the hailstones.

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CONNECTION OF A BACTERIAL ORGANISM WITH CURLY LEAF OF THE SUGAR BEET

RALPH E. SMITH AND P. A. BONCQUET

WITH PLATE XVII AND ONE FIGURE IN THE TEXT

In a recent communication upon this peculiar disease published in this JOURNAL[1] we pointed out the presence of a specific lesion showing itself in the phloem of the fibro-vascular bundles of all affected plants or parts of plants. We also mentioned the fact of having isolated a certain bacterial organism from all affected parts of sugar beet plants, which organism appeared to be a constant inhabitant of affected tissues. We also mentioned the detection with the microscope in the lesions above mentioned of certain bodies, apparently of the nature of foreign organisms but of an undetermined nature.

Lesion. Figures 1 and 3 of Plate XVII in the present article show the location and appearance of the characteristic lesions in a freehand section of a living sugar beet petiole, stained with dilute neutral red. In figure 2, Plate XVII, is shown a microtome section of a beet root with considerably advanced lesions in the phloem. These diseased tissue areas correspond with the black spots seen with the eye when the root of a curly leaf beet is cut across.

Organisms in tissues. A large amount of histological work performed since our last article was written has shown that these lesions in all parts of affected plants, even out to the most minute, youngest vascular bundles in the leaves, are constantly inhabited by a specific bacterial organism. This organism, furthermore, has the remarkable habit of living within the cells, inhabiting the sieve-tubes of the phloem and forming therein a ring or layer just inside the wall. In figure 4 Plate XVII is shown a cross section of part of a leaf vein phloem containing a young curly leaf lesion. In the sieve-tube indicated by the arrow a circle of bacteria-like bodies may be seen lining the wall. These are shown more clearly in the longitudinal section in figure 5. Since these photographs were made many more sections have been cut and examined and the fact established beyond any possible doubt that we have in the sugar beet disease a foreign organism living abundantly in the interior of the sieve-tubes. In appearance the organism shows itself mainly in two rather distinct forms, as may

[1] Phytopath. **5**: 103. 1915.

be seen in the photographs. In one of these forms there are symmetrical, ring-like bodies with a comparatively thick wall. Individuals of the other form are elongated with a dense portion at each end. Intermediate between these two are forms which consist of a slightly oval ring with a thickening at each end. The bi-polar forms average 1.1 by 1 μ in size,

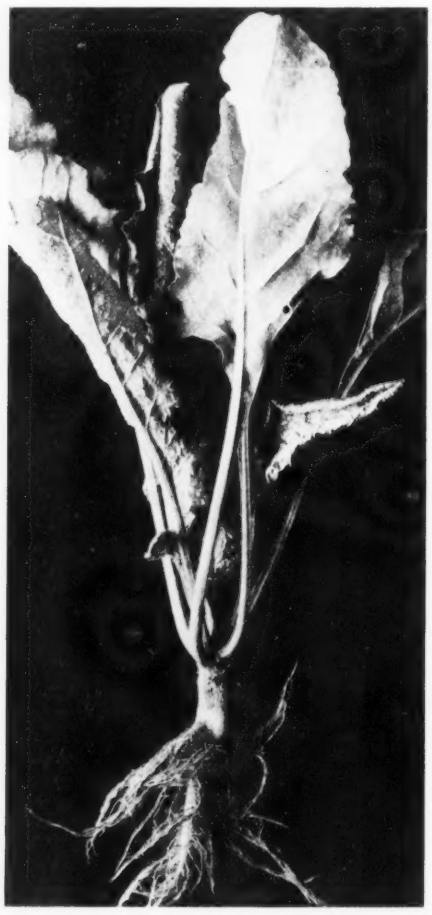

FIG. 1. Young sugar beet plant, typically affected with curly leaf.

with the smallest about 0.7 by 0.5 μ. The ring form tends to be fairly large with a diameter often equalling the greatest length of the bi-polar individuals. These bodies are somewhat refractory to the usual bacterial staining methods, but vigorous stains like Leishman's and Giemsa bring them out quite easily. For temporary purposes dilute neutral red

is effective. For staining paraffin sections on the slide we have come to prefer the gold chloride method, treating first for 12 hours with 1 per cent gold chloride, then for 12 hours with 0.25 per cent formic acid; all in the dark and with very thorough washing in water between the two chemicals and after the treatment.

It was thought for a time that the ring and bi-polar bodies might represent two different organisms, but further study makes it appear that all the individuals have the same structure, varying in appearance with the position in which they happen to lie. For a long time we were unable to establish to our own satisfaction any connection between the bodies or organisms seen with the microscope and that isolated from the same tissue in cultures. The latter, as we mentioned in our previous article, seems to resemble *Bacillus dianthi* Bolley and, for convenience, we will call it by this name for the present, at least. Grown in ordinary media *B. dianthi* is a typical rod-shaped organism with a strong tendency to the formation of zoogloea. By growing this organism in special media, however, particularly in 0.5 per cent lithium chloride in nutrient bouillon, we have succeeded in exactly reproducing in great abundance the bi-polar form seen in the tissue, and a small proportion of individuals of the ring form, although we have not yet in cultures obtained the latter in any such abundance as it occurs in the tissues. Sufficient results have been obtained along this line to convince us strongly that we are dealing with one and the same organism throughout the whole matter.

Bacillus dianthi as a sieve-tube inhabitant of the sugar beet not peculiar to the curly leaf disease. For some time after the discovery of the remarkable presence of this organism in the sieve-tubes of curly top affected beets, we were inclined to assume that the specific incitant of the disease had been found and that the effect of the insect *Eutettix tenella* Baker upon the sugar beet was an act of infection with this organism. Further study, however, in an effort to determine exactly the limits of this disease, has revealed the surprising fact that *B. dianthi* inhabits the sieve-tubes of sugar beets and related plants very commonly in cases where there is no possibility of the plants ever having been attacked by *Eutettix tenella* and cases which cannot be considered as representing this particular disease. The fact was early noticed in our work that there exist in sugar, garden and stock beets, Swiss chard and similar plants a great variety of foliage types representing various forms of wrinkling, curling and distortion. Many or in fact most of these forms represent nothing which could be called a pathological condition except in the strictest sense of the word. Such plants grow and develop normally but show many forms of curled, roughened and distorted leaves, as may be seen by an examina-

tion of any garden or field containing these plants. Through histological study of all sorts of types of distorted beet foliage growing in California the discovery has been made that in all these cases *Bacillus dianthi* inhabits the sieve-tubes to a greater or less extent and that the abundance of this organism corresponds directly with the degree of abnormality or distortion showing itself in the foliage. In a perfectly smooth beet leaf with all portions symmetrically developed and with the main lateral veins proceeding symmetrically and at the same angle from the mid-vein, careful search fails to reveal the presence of *B. dianthi*. In wrinkled, curled, or distorted leaves, however, the organism has been found in the veins adjacent to such distortion and even in the main root of the plant. It was thought for a time that plants with these various types of foliage represented various types of the real curly leaf disease induced by *Eutettix tenella*. Subsequently, however, plants which had been grown from the seed in very carefully protected cases and with no seeming possibility of access of this insect, revealed the same condition.

At this point the senior author, in order to settle the fact beyond question, made a trip to various Eastern localities for the purpose of obtaining beet material far beyond the known range of *Eutettix tenella*, the eastern limit of which is supposed to be considerably west of the Mississippi River. Sugar beets, garden and stock beets, and various forms of Swiss chard were found and examined in the sugar beet districts of southeastern Michigan and northwestern Ohio, and also at Amherst, Massachusetts. In these districts no trace of typical curly leaf was found, but practically all other types of distorted or unsymmetrical beet foliage previously observed in California were encountered in abundance. Upon our return to California preserved material was sectioned and examined whereupon the fact developed that *Bacillus dianthi* was common in the sieve tubes of all these plants and here again varying in abundance with the degree of morphological abnormality of the leaves.

From this it appears certain that the incitation of curly leaf in sugar beets by *Eutettix tenella* is not necessarily an act of infection with this organism, or at least that the presence of *B. dianthi* in the sieve-tubes is not the only factor necessary to produce curly leaf. At the same time the organism has a certain pathological effect and the problem of the etiology of the curly leaf is very greatly complicated by the fact of its occurrence. It would appear that the insect must either increase the virulence of *B. dianthi* in some manner, or else it introduces an entirely different factor.

A horticultural variety of beet produced by Bacillus dianthi. One of the most interesting results of our study is connected with a certain variety of beet, specimens of which were found growing upon the grounds of the Massachusetts Agricultural College at Amherst. This is the so-called

"lettuce leaved" beet, apparently a form of chard, with large, very much curled or wrinkled leaves, similar to those of the Savoy cabbage. Sections of the petiole and veins of these leaves have shown that the sieve-tubes are full of the organism which we are calling *Bacillus dianthi*. Such being the case, it is natural to connect the extreme roughening or wrinkling of the leaves with the remarkable abundance of the organism in the tissues, and conclude that this variety owes its peculiar type of foliage entirely to the presence of this foreign organism.

Bacillus dianthi in beet seed. Our search for this organism in the tissues of sugar beets has followed up the development of seed stalks, blossoms and seed and we have found that in beets with decidedly distorted foliage the development of the organism in the sieve-tubes keeps pace with the growth of the plant and that the foreign invader may be found high up in the seed stalk many feet from the ground, in the lateral branches, in the pedicels of the blossoms, and actually in the vascular tissue of the seed itself. This fact would seem to indicate that the organism may be carried over in the seed and find its way into the new plants from this source rather than from exterior infection. This would likewise account for the perpetuation of the "lettuce leaved" type or variety of beet mentioned above which apparently comes true from seed.

Inoculations. All our efforts to produce curly leaf or any pathological or abnormal condition in sugar beets by artificial inoculation, either with the juice of diseased plants or with cultures of *Bacillus dianthi*, have thus far entirely failed. Attempts have been made by atomizing material upon uninjured surfaces, through large and small wounds in the leaves, petioles and roots, and by inserting the material into various parts of the plant in capillary glass tubes which were broken off and allowed to remain in the tissue. These inoculations have been made at various degrees of temperature and humidity, but all without effect.

Transmission by grafting. Curly leaf has been easily and typically produced in healthy plants by grafting into the top of the root pieces of the root of an infected plant, with growing buds attached.

Eutettix tenella from wild plants not pathogenic. In another article contained in this number of Phytopathology Messrs. Boncquet and Hartung announce the important discovery that when taken from wild plants far removed from beet fields *Eutettix tenella* has no effect upon sugar beets, but is able to produce the typical disease only after feeding upon plants which have the disease. In our own work this fact has been extensively tested and abundantly corroborated. Fully two thousand insects obtained from the Tulare Lake region, California, from *Atriplex tularensis* Jepson, and *Chenopodium album* L., have been tested out upon several hundred different sugar beet plants without the production of curly leaf or any

other visible effect in a single instance. After feeding upon curly leaf sugar beets, however, for a period which at most need not exceed three hours, the same insects become highly pathogenic. It is of course altogether possible that some other wild plant than the one from which we obtained our insects may harbor the pathogenic factor, but it seems at least to be demonstrated that this factor is not inherent in the insect but must be obtained by it through feeding upon plants affected with curly leaf, or at least those containing a factor which incites this disease.

Incubation period in the body of the insect necessary. Many experiments have been tried of allowing the insects to feed upon curly leaf sugar beets for various lengths of time, then moving them on to healthy plants and transferring from plant to plant at various intervals in order to determine how quickly the insect can become infectious after feeding upon the diseased plants. We have found, as mentioned in the last paragraph, that no more than three hours feeding time is necessary for the insect to obtain the pathogenic factor. All the experiments tried thus far, however, go to show that the insect is not immediately pathogenic after the act of feeding, but that a period of at least twenty-four hours, but certainly not much more than this, must elapse before it can produce the disease. In one experiment, for instance, twenty-five wild insects (which had previously been feeding upon healthy sugar beet plants without any effect upon them) were allowed to remain for three hours upon a curly leaf plant. They were then transferred singly to twenty-five healthy plants, the insect upon each plant being confined to one leaf in a small glass tube. At the end of three hours each insect was removed and placed upon a new plant, again after a period of twenty-one hours had elapsed, and again after twenty-four hours more. After this the insects, now reduced to eighteen in number, remained upon the same plants for six days. Each set of plants was kept at all times, from the planting of the seed to the conclusion of the experiment, in Eutettix-proof cases. In the twenty-five plants upon which the insects passed the first three hours after feeding for three hours upon a diseased plant, and among the same number of plants upon which they passed the following twenty-one hours, no effect whatever was produced. Of the twenty-five which were used during the second twenty-four hour period three became typically affected with curly leaf after the usual period of twelve to fourteen days. Of the eighteen plants upon which the insects remained for six days commencing forty-eight hours after they first fed upon the diseased plant, eight became affected.

Several other experiments along the same line have given the same indication, namely that Eutettix does not mechanically transfer the pathogenic factor from diseased to healthy plants but that some development

or change takes place in the factor within the body of the insect during the first few hours after it feeds upon the diseased plant. A great many experiments have been made which show that no more than forty-eight, and possibly not over twenty-four, hours is necessary for the insect to become pathogenic.

Credit is due to Mr. H. A. Lee for carrying out the details of much of the work described in this article, and for many helpful suggestions in connection with the same.

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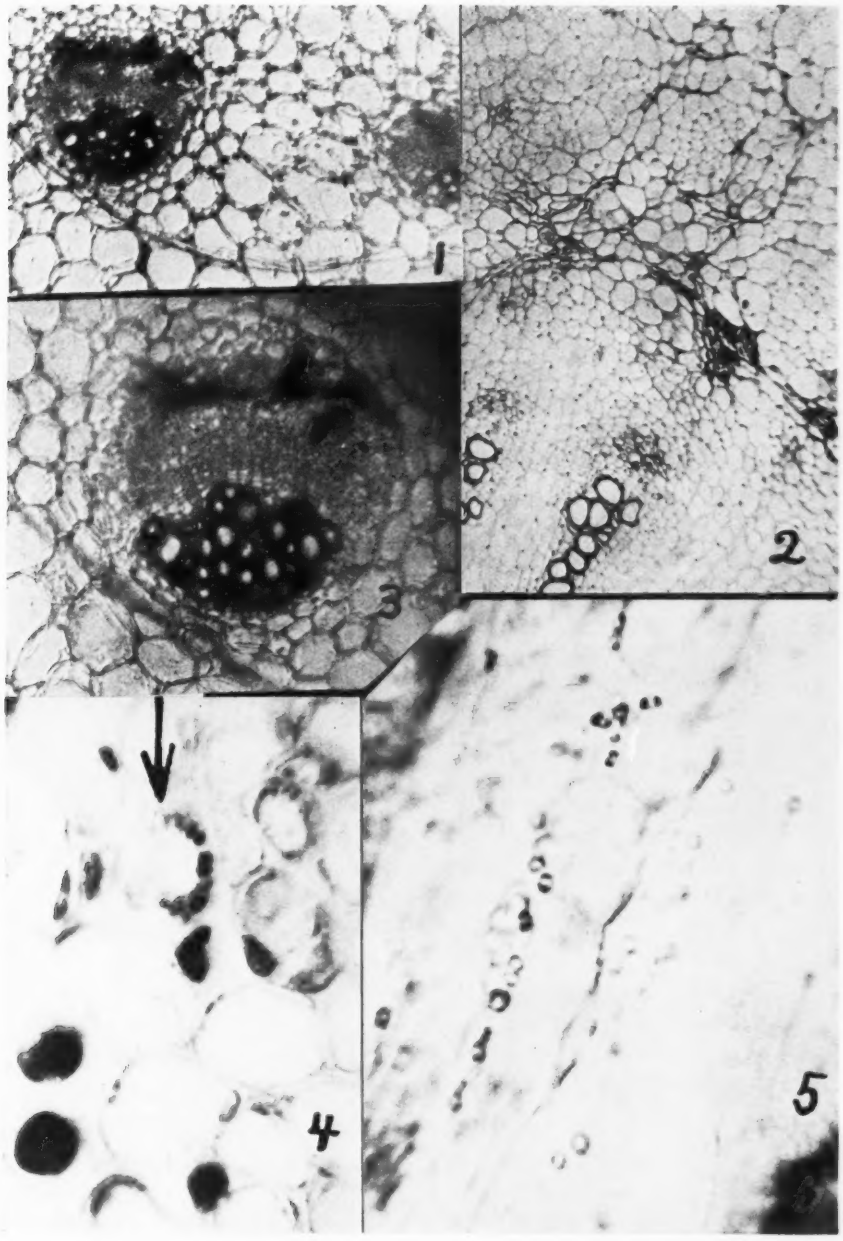
PLATE XVII. HISTOLOGICAL CONDITIONS OF CURLY LEAF DISEASE

FIGS. 1 and 3. Curly leaf lesion in phloem of sugar beet leaf veins.
FIG. 2. As in figure 1. Microtome section, more enlarged.
FIG. 4. Bacillus dianthi in sieve tubes.
FIG. 5. Bacillus dianthi in longitudinal section of sieve tube.



SMITH AND BONCQUET: CURLY LEAF DISEASE

INSECT CONTROL IMPORTANT IN CHECKING FIRE BLIGHT

A. C. Burrill

The important part played by insects in the dissemination of plant disease pathogenes is each year becoming more evident. It has therefore seemed worth while to give some attention to this from an entomological viewpoint, especially with reference to fire blight, since the writer is convinced that the control of the insect carriers offers the easiest way to check the blight. The writer's interests at the outset were chiefly with aphids, but as his results will show, he has found that other Homoptera, leaf hoppers, may play an important part. Although trials were planned before the writer knew of Stewart's latest work along these lines, especially with Heteroptera (1, 2, 3), he wishes to record his indebtedness to Stewart's published reports for further suggestions, as well as to the earlier one of Jones (4). Stewart plated *Bacillus amylovorus* successfully from aphids which had fed on blighting shoots of apple, thus showing that the aphids may function as germ carriers. He further observed that in apple nurseries, fire blight epidemics follow rapidly in the wake of aphid epidemics.

EXPERIMENTAL STUDIES

It seemed practicable to study the habits of aphids and leaf hoppers more closely in relation to the spread of blight under Wisconsin conditions. The wild crab apple[1] which is common about Madison blights badly and is infested with various apple insects. It was therefore chosen for experimental study, in a field where both adult trees and sprouts, or seedlings, occur. Madison had a severe blight epidemic in 1914 which included a first attack in a week of humid hot weather in early June, a second in the hot muggy week of July 4, and further minor outbreaks during several muggy dogday periods in August. Throughout this growing period, none of the seedlings blighted, but on the adult trees in June those water sprouts blighted which had aphids.[2] Therefore seedlings which appeared blight-

[1] *Pyrus coronaria* L. intermediate with *P. ioensis* (Wood) Bailey.

[2] *Aphis avenae* Fab. and *A. mali* De Geer often intermingled on the same shoot and tended by an ant *Formica rufa* subsp. *obscuripes* Forel (?). J. J. Davis, United States Bureau of Entomology, examined microscopic slides of aphids taken from these same trees the preceding fall and pronounced them *Myzus persicae* Sulz., an illustration of the many changes in aphis population on a given tree during a single year.

free were chosen for some colonization experiments. Seedlings, four to six feet high, were covered with glazed paper sacks (glasseen), each arranged to cover two or more twigs, so as to give sufficient controls in each trial. Within two of these glasseen bags, a terminal shoot was further isolated in a mica chimney closed at each end by tightly-fitting aseptic gauze bands, so that aphids could not pass through. A small amount of moist cotton was placed in each bag with the idea that the moist atmosphere might favor the growth of the blight germ.

On the larger crab trees, badly blighting leaves infested with living aphids were carefully chosen. Such a leaf with aphids was placed in each mica tube, and the aphids left to find their way from the shrivelling leaf to the fresh twig adjacent. All other insects had been brushed off these twigs before they were enclosed in the bags. The same method was applied to leaf hoppers (*Empoasca mali* LeBaron) except that they were caught in paraffined capsules and liberated on the bagged test twig after the bag was in place. In an attempt to make a test parallel with the trial of leaf hoppers the writer was unsuccessful in a search of an hour in securing a single tarnished plant bug, *Lygus pratensis* L., in the weeds which were abundant all about the crab trees.

These trials were started June 19, and the results were recorded June 30, 1914. In experiments 1 and 2, a mica tube contained the insects and twig on which blight was expected, while other twigs, outside of the tube but within the bag served as useful controls both because no insects were present and because the effect of a bag with wet cotton needed to be compared with unenclosed shoots.

Experiment 1. Winged and apterous aphids on blighting leaf enclosed in mica tube. Result, eight inches of test twig blighted. Controls in bag outside mica chimney remained healthy.

Experiment 2. Apterous aphids on blighting leaf enclosed in mica tube. Result, one to two inches of test twig blighted. Control twigs did not blight.

Experiment 3. Apterous aphids similarly enclosed in bag, no tube. Result indefinite, since twig had three leaves with browning tips nearly as in blight, and four more leaves yellowing, the latter not adjacent to each other. Controls outside of bag, no blight or abnormality.

Experiment 4. Apterous aphids moved to a blighting leaf and in a few hours returned to the original blight-free twig from which they were taken; enclosed in bag, no tube. Result, six to ten inches of test twig blighted. As the aphids were not confined by mica tubes in this and the last test, it was not surprising to find several leaves on adjacent twigs within the bag which were partly discolored, suggesting infections when the aphids retreated from the blighting terminal shoot. No blight on

twigs outside bag. The blight resulting as reported above seems to show immediate infectivity by aphid carriers.

Experiment 5. Winged and apterous aphids enclosed as in Experiment number 3. Result, two to six inches of each of several test twigs blighted within bag, no blight without. The blighted twigs were mostly laterals near base of main shoots, where most aphids had located after test began. However, the main shoots showed no blight though aphids occurred near tips. The main shoots may have had more mature tissues.

Experiment 6. Enclosed as in number 4. Aphids from an apparently healthy aphis-infested twig placed on a blighted aphis-free leaf so that they could wander back to former twig. Two leaf hoppers were present on healthy twig and were so enclosed with the aphids. Result, one to three inches on each of several test twigs blighted within the bag but none outside the bag, although some of these controls continued to be infested with aphids. Unlike Experiment 4, both lateral and terminal twigs blighted.

Experiment 7. Two leaf hoppers, from blighted leaves of crab apple, and a blighting twig transferred to an apparently healthy twig which was already infested by two other leaf hoppers supposedly uninfected. Result, four inches of test twig blighted. Twigs immediately adjacent to test twig at point where bag was tied, but outside bag, seemed affected. All other shoots and twigs of seedling seemed healthy.

DISCUSSION OF EXPERIMENTAL RESULTS

Where mica tubes were used, no twigs blighted within the bag save in the tube, thus showing that the moist chamber made by the bag did not induce blight but that blight occurred only where insects, known to have sucked from half-blighted leaves, were confined.

In experiments 4 and 6 aphids were sought from apparently uninfected twigs. It may be assumed that the aphids were previously uninfected. The right to this assumption is based on the fact that no other parts of the young tree on which they also occurred developed blight. This clean colony occupied many other twigs which served for checks.

Experiment 7 shows that leaf hoppers may act as carriers of blight and, judging from observations on these insects while inspecting nurseries during the last five years, the writer believes that they are the most important carriers of blight in Wisconsin during July and August.

CONCLUSIONS

The chief problems of fire blight transmission and consequently of its control center about the question as to what species of insects most com-

monly carry blight and as to what times such species are abundant during May, June, and July, the chief months for blight. In this connection it is noteworthy that fire blight according to observations appears in waves or definite maxima during the early growing period of some fruits, and the attempt has been made to correlate with these waves corresponding waves of development of sucking insects predatory upon the trees.

Waite (5) has shown that bees and probably wasps and flies carry blight while working upon the flowers. Following this period various other observers have attributed the further spread of the organisms to the winged green apple aphis (6) and to bark borers (4) in the orchard, to the tarnished plant bug and some other Heteroptera (3) in the nursery (2), to apple tree borers in apple collar blight in Pennsylvania (7), and to click beetles and ants as well as to the drip of rains in California orchards (8). The writer's tests add *Aphis avnae* and *Empoasca mali* to the list, from which many other suspected insect species are purposely excluded. These two species were chosen as the most common insects on Wisconsin apple trees. The writer does not doubt Stewart's finding tarnished plant bugs, *Lygus pratensis* L., most abundant on New York apple trees during July,[3] but is unable to prove that his conclusions hold for Wisconsin, since this tarnished plant bug is not the most important sucking insect in the nursery[4] until August. In July, the month he seeks to correlate these bugs with blight, there are in Wisconsin, hosts of leaf hoppers on apple nursery stock. If these observations for the respective states prove indisputable, a further problem presents itself as to how widely conditions vary in different states or environments with regard to the dominant species of sucking insects and how great is their fluctuation in numbers from year to year and at different times in the year. In this connection, none of the writers seem to emphasize the fact that few hibernated tarnished plant bugs and leaf hoppers appear at the time of the opening of the buds and blossoms. With them the writer fails to conceive how so few can account for the multitudinous early infections beyond admitting their probable rôle as first carriers of blight. The tarnished plant bug feeds on many weeds and can less often transmit germs directly to other apple shoots on account of intermediate feedings on weeds. In contrast, apple leaf hoppers are more strictly limited as to host plant. In Wisconsin nurseries and orchards, leaf hoppers and aphids are far more abundant than tarnished plant bugs. Several field observations in 1914, in other parts of Wisconsin, seem to support the tests and the theory involved above, but are omitted for lack of numerical data.

[3] Especially nursery trees. Stewart (2), p. 340.

[4] Stewart (2), p. 368.

Weather conditions seem to correlate with blight waves and insect waves. For example, late frosts may stop blight by killing aphids and buds as happened on April 23, 1910, in Wisconsin. Frost-free backward springs foster insect emergence and retard blossoming until large numbers of blight-carriers are at hand to infect the trees, according to Reed (9).

If further evidence supports this view, the control of insect carriers of blight must prove far cheaper than the present method of tree to tree pruning, which is not only expensive but at the best only partially effective. I do not wish, however, to imply that we should relax our attempts to eliminate hold-over cankers, a subject still much in need of study.

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9. REED, G. M. An unusual outbreak of apple blossom blight (Missouri conditions). Phytopathology **4**: 27-30. 1914.

PHYTOPATHOLOGICAL NOTES

The comparative effect upon sugar beets of Eutettix tenella Baker from wild plants and from curly top beets. The writers desire to report the following experiment as throwing valuable light upon the relation of *Eutettix tenella* to the curly leaf disease.

One hundred specimens of *E. tenella* obtained from the Tulare Lake region of California in May and June, 1915, were confined singly upon normal sugar beet seedlings. At the same time about one hundred and fifty individuals which had been living upon curly leaf sugar beets at Spreckels, California (where this experiment was made), were similarly

FIG. 1. Comparative effect upon sugar beets of Eutettix from Atriplex tularensis and from curly top beets. In plat *D* one insect from diseased beet was placed upon each plant. In plat *B* there was a similar application of Eutettix from Atriplex. Almost every plant in *D* badly affected with curly top, in *B* no trace of the disease.

confined upon healthy plants. The latter promptly produced very severe typical curly leaf upon almost every plant in a most decided fashion. The wild insects had no effect whatever and the beets are still in normal condition. Sixty of the wild insects were removed from these plants after remaining upon them for three weeks and placed upon other beets badly affected with curly leaf. They were then removed from those plants at different times after remaining upon them for a period of from three to seven days and placed upon other normal plants. At least fifty of the latter are at the present time typically affected with curly leaf, while the remaining ten are somewhat doubtful. About twenty wild insects have been kept constantly upon normal beets since May without showing any effect whatever. These experiments show most strikingly that the wild insects used, coming from Artemisia or Atroplex species in the Upper San Joaquin Valley, had absolutely no power to produce curly leaf, while similar insects reared at Spreckels upon diseased beets were extremely pathogenic. They also show that the wild insects become pathogenic after feeding for a few days upon affected plants.

P. A. BONCQUET AND WM. J. HARTUNG

Mildew on black currants. On July 10, 1915, a block of black currant nursery stock was noticed to be severely affected with mildew. Although several of the larger nurseries in New York State have been visited many times each season for the past seven years, this is the first infection of mildew ever observed by the writer on black currant, *Ribes nigrum*. All of the varieties, Champion, Naples and Saunders, in the block were affected and several adjoining rows of red currants, *Ribes rubrum*, also were slightly attacked. The black currants were separated from a large block of Downing and Industry gooseberries by a driveway thirty feet wide. Although a careful search was made on this date no infections of mildew were apparent on any of the gooseberry bushes. On August 27, a single infected shoot was found on an Industry bush at a distance of about one hundred feet from the black currants; this was the only infection which appeared on the gooseberries throughout the summer.

The general characteristics and measurements of the fungus found on the currants are in accordance with those of *Sphaerotheca mors-uvae* (Schw.) B. & C., which is commonly found on gooseberries; and Salmon has reported this species as attacking red and black currants in Europe. Assuming that the same species of mildew affects both currants and gooseberries, the writer is unable to account for the absence of the mildew on the gooseberries, particularly on the very susceptible variety Industry, except on the basis of biological specialization.

V. B. STEWART

Citrus mildew. Mr. C. N. Carter's[1] paper on a powdery mildew on citrus in your issue of June, 1915, has induced me to send you the accompanying rough notes on citrus mildew in the hope that they may be of interest to American phytopathologists.

In Ceylon, and, I am given to understand, in India also, mildew of citrus is a common disease. Indeed, in Ceylon it is the worst disease of citrus we have.

It was first recorded for Ceylon by Berkeley[2] in The Gardeners' Chronicle, n. s., I, p. 477 (1874), as follows:

"It is now some years since we received from Lieut-Colonel Grant, of Wellington, Neilgherries (i.e., South India—T. P.) some leaves of Orange and Mango which were infested with the Oidioid form of some Erysiphe. . . . . Our attention has lately been recalled to the subject by a sprig of Orange from Mooloya, Hewahette, Ceylon (4000 feet), sent by Dr. Thwaites under No. 1230, too late to be included in the account of Ceylon Fungi lately published in the Journal of the Linnean Society. The Wellington specimens exhibit, except in one minute spot, nothing more than a form of Oidium with rather long, almost truncate joints. In the Ceylon specimen there is a trace of these though most have been absorbed, and in their place a multitude of both conidio-morphic and spherical pycnidia, pouring out a profusion of stylospores, exactly as in the figure which Tulasne[3] gives in his Carpologia I, tab. V, fig. 3. It is most probable therefore that the species is one of the forms of *Erysiphe communis*, and it is the more interesting because the genus is not hitherto recorded as occurring in the Eastern Indies or the neighboring islands. The perfect fruit has not yet been found. As the vine mildew has extended to tropical climates and is capable of being propagated on other plants it becomes a matter of interest to inquire whether the parasite in question is not identical and whether it has not been introduced with it."

The pycnidia noted by Berkeley are of course those of Cicinnobolus, which is especially common on mildews in Ceylon. We have in Ceylon both *Plasmopara viticola* and the conidial stage of *Uncinula spiralis*, both no doubt introduced, but oidia are so general on native plants that there is no need to consider Berkeley's suggestion.

Mildew of citrus has since been recorded for Ceylon in numerous reports, etc., intended for local information, and in the Annual Reports

[1] Carter, C. N. A powdery mildew on citrus. Phytopathology **5**, no. 3:193–196, p. 12. June, 1915.

[2] B(erkeley), J. M. Gard. Chron. n. s. **1**, no. 15:477–478. April 11, 1874.

[3] Tulasne, L. R., and Tulasne, Charles. Selecta Fungorum Carpologia **1**: pl. 5, fig. 3. Parisiis, 1861.

of the Mycologist. In the Year Book of the Ceylon Agricultural Society,[4] it is stated, "Orange and other citrus trees in Ceylon are specially subject to diseases, one of the commonest of which is a mildew which covers the leaves and young shoots with a thick white coating. This usually occurs toward the close of each monsoon, and in some districts kills back the shoots so regularly that the trees never grow up."

As citrus cultivation is of no importance in Ceylon, work on this disease has been shelved in favor of more urgent investigations. The disease occurs on varieties of sweet orange, and on mandarin, but is especially destructive on pomelo (= grape fruit). I have not observed it on Lime, which is common in Ceylon, or on lemon or citron, which are rare. On the older leaves the appearance of the disease is similar to that described by Mr. Carter: the leaves are attacked locally, and ultimately exhibit only effused blackened areas; they do not necessarily fall off. On the young shoot, however, the effect is more serious; the young leaves and the stem may be densely covered with a white powder, and the shoot ultimately killed back for a length of about a foot. Where this occurs after almost every monsoon, i.e., every six months, as it does in some localities, the trees never grow up, but form only low stunted bushes which either die out or are uprooted by the owner in disgust.

Measurements of the conidia of the Ceylon species give 36 to 42 by 15 to 18 μ as the dimensions, as against 20 to 28 by 10 to 15 μ given by Carter. It is probable therefore that the Ceylon fungus is a different species. In the absence of any experiments, it is also possible that the forms on the various species of citrus in Ceylon are not all the same. But in any case it seems desirable to put on record that mildew (Oidium) of citrus is a well-known and wide-spread disease, or group of diseases, in Ceylon, and thus to indicate the possibility of its introduction into America.

The cultivation of citrus fruits is, for various reasons, not a commercial proposition in Ceylon. But were Ceylon in other respects suited for it, the prevalence of mildew would practically render it impossible.

Contrary to the opinions generally expressed, mildews, or at least their Oidium stages, are common in the Eastern tropics. It is frequently stated that in the tropics Meliola replaces Erysiphe. So far as Ceylon is concerned that is not true: species of both genera are common. But no perithecial stage of Erysiphe has yet been found in Ceylon. It may be noted that the occurrence of Meliola is, in part if not altogether, conditioned by the presence of insects which secrete "honey dew," and cannot be considered as antithetical to the occurrence of Erysiphe.

[4] Petch, T. Notes on fungus diseases. Yearbook Ceylon Agr. Soc. **1914/15**: 65–67. 1914.

As possibly bearing upon the citrus mildew, it may be recorded that an Oidium has been found on *Aegle marmelos*, a native species of Rutaceae. Of interest in another direction is the fact that oak trees (*Quercus pedunculata*), grown in the hill district of Ceylon from seed imported from England, have been attacked every year since the writer has known them. (i.e., since 1904), and probably earlier, by an Oidium, and in consequence are merely scrub. Another species is prevalent on tobacco. Collections of Oidia from Ceylon, including the citrus mildew, have been submitted to European specialists from time to time during the last twenty years, but the latter have preferred to demand the production of perithecia rather than refer the conidial stages to any species. Specimens of the Oidium on Quercus have been contributed to Sydow's Fungi Exotici Exsiccati.

T. PETCH

Personals. Prof. H. M. Jennison, assistant professor of Botany and Bacteriology in the Montana Agricultural College, Bozeman, Montana, will do graduate work during the ensuing year at the Missouri Botanical Gardens while on leave of absence. Address Missouri Botanical Gardens, St. Louis, Mo.

Dr. George Osner, field assistant in Pathology in the Bureau of Plant Industry, stationed at Plymouth, Indiana, has been appointed associate botanist in the Indiana Experiment Station at Purdue University, Lafayette, and has entered upon his duties.

LITERATURE ON AMERICAN PLANT DISEASES[1]

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August to September

American Phytopathological Society. Report of special meeting of the American Phytopathological Society and the Pacific division, University of California, Berkeley, California, August 3 and 5, 1915. Phytopathology **5,** no. 5: 291–295. October, 1915.

Anderson, Jacob Peter. Fungus diseases. Alaska Agr. Expt. Sta. Rpt. **1914:** 26–27. 1915.

Appel, Otto. The control of cereal and grass smut and the Helminthosporium disease in Holland and Germany. Phytopathology **5,** no. 4: 230–232. August, 1915.

Arthur, Joseph Charles. Uredinales of Porto Rico based on collections by F. L. Stevens. Mycologia **7,** no. 5: 227–255. September, 1915.

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Ashby, S. F. Notes on diseases of cultivated crops observed in 1913–14. Bul. Dept. Agr. Jamaica n. s. **2,** no. 8: 299–327, pl. 62–63. August, 1915.

Ballard, William Salisbury. Apple mildew. (Abstract.) Phytopathology **5,** no. 5: 292. October, 1915.

Barrett, James Theophilus. Coryneum fruit spot of apricot. (Abstract.) Phytopathology **5,** no. 5: 293. October, 1915.

——— Fruit stain and wither-tip of citrus. (Abstract.) Phytopathology **5,** no. 5: 293. October, 1915.

Colletotrichum gloesporiodes.

------ Mottled leaf of citrus. (Abstract.) Phytopathology **5,** no. 5: 292. October, 1915.

"No specific cause has been discovered and the disease is still classed as a physiological disease."

------ Observations on prune rust, Puccinia prunispinosae Pers., in southern California. (Abstract.) Phytopathology **5,** no. 5: 293. October, 1915.

Barss, H. P. Bacterial canker of cherry and filbert disease. (Abstract.) Phytopathology **5,** no. 5: 292. October, 1915.

Batchelor, L. D. Variation and blight resistance among walnuts. Mo. Bul. State Com. Hort. [California] **4,** no. 9: 428–430. September, 1915.

Blodgett, Forest Milo. Sweet pea powdery mildew. Phytopathology **5,** no. 4: 237. August, 1915.

Microsphaera alni.

[1] This list aims to include the publications of North and South America, the West India Islands, and islands controlled by the United States, and articles by American writers appearing in foreign journals.

All authors are urged to coöperate in making the list complete by sending their separates and by making corrections and additions, and especially by calling attention to meritorious articles published outside of regular journals. Reprints or correspondence should be addressed to Miss E. R. Oberly, Librarian, Bureau of Plant Industry, U. S. Dept. Agric., Washington, D. C.

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——— Report of the plant pathologist. Porto Rico Agr. Expt. Sta. Rpt. **1914:** 27–30. 1915.

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Fawcett, Howard S. Citrus canker in Florida and the Gulf states. Mo. Bul. State Com. Hort. [California] **3**, no. 12: 512–513. December, 1914.

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"Gummosis is caused by the fungus *Pythiacystis citrophthora* S. and S. and melaxuma by a fungus probably of the genus *Dothiorella*.

——— Spotting of citrus fruits. Mo. Bul. State Com. Hort. [California] **4**, no. 9: 434–435. September, 1915.

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Disease due to lack of oxygen in a soil which was saturated with water; i.e., that the roots were suffocated.

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Chinese sand pear and the birch-leaved pear.

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Osmun, A. Vincent, and **Anderson, Paul Johnson.** Ringspot of cauliflower. Phytopathology **5,** no. 5: 260–265, 4 fig. October, 1915.

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"Until we know the real cause of curly-top there can be but faint hope of solving the more important economic problem of its control."

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[PHYTOPATHOLOGY, for October, 1915 (**5:** 247–295), was issued October 1, 1915.]

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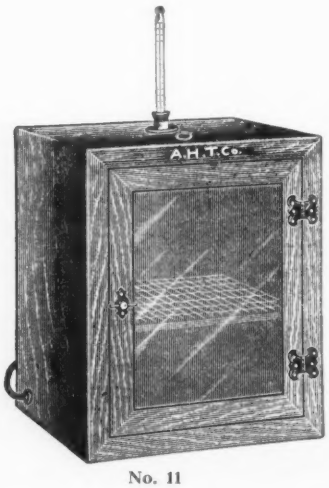

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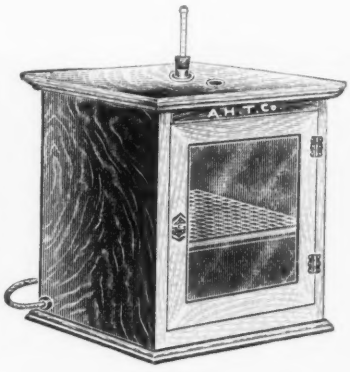

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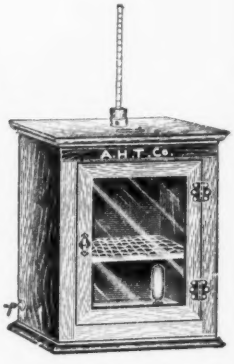

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